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ESSENTIALS OF SANITARY SCIENCE

ἐπιφᾶναι τοῖς ἐν σκότει καὶ σκιᾷ θανάτου καθημένοις·

Pray for all souls that mourn their dead—
  Pray for all souls that they may see
  A light, from the great time to be,
Already streak the East with red ;

Behind whose twilight wait unseen
  A perfect earth, perfected man—
  To finish all that we began,
To be what we would fain have been.

From "A Requiem," by Louisa Shore.

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ESSENTIALS OF SANITARY SCIENCE

BY

GILBERT E. BROOKE

M.A. CANTAB.; L.R.C.P. EDIN.; D.P.H.; F.R.G.S.; FELL. OF THE ROYAL INSTITUTE OF PUBLIC HEALTH; PORT HEALTH OFFICER, SINGAPORE; LECTURER IN HYGIENE AND EXAMINER IN CHEMISTRY AND PHYSICS TO THE MEDICAL SCHOOL OF THE STRAITS SETTLEMENTS; FORMERLY HEALTH OFFICER, GOVERNMENT MEDICAL OFFICER AND DISTRICT COMMISSIONER, TURKS ISLANDS, WEST INDIES

AUTHOR OF 'A HYGIENE READER FOR SCHOOLS,' 'TROPICAL MEDICINE, HYGIENE AND PARASITOLOGY,' 'AIDS TO TROPICAL MEDICINE,' ETC.

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FOREWORD

An apology is needed for adding a new work on Sanitary Science to the long list of admirable volumes on that subject with which the past has dowered us.

This little volume is intended primarily as a manual for students preparing for the D.P.H. examination, though it is hoped that it may also be useful to all sanitary officers and medical officers of the Public Services.

The reason for its appearance lies in my own experiences. When preparing for the D.P.H. examination, I found, as I think most students find, that the ordinary manual, or Text-book of Hygiene, does not carry one far enough. To refresh the Hydrostatics and Heat, other text-books on those subjects must be procured. Further books, again, will be required for the laboratory work in Water Analysis, in Bacteriology, in Food Analysis; also for the Parasitology, the Geology, etc., etc.

Thus the student has to provide himself with, or gain access to, quite a library of volumes at considerable expense and trouble.

I hope the present work will be found to obviate all these disadvantages, in that it *aims at covering all the necessary ground.* I have endeavoured to make it thoroughly practical, so that it shall be **as useful and indispensable in the laboratory as it is in the study.**

My own D.P.H. notes (compiled during reading and laboratory work) have been taken as a basis, and the

whole has been amplified by reference to almost all the many standard works, large and small, on Hygiene, Bacteriology, Physics, Chemistry, Geology, etc.

In such a student's compilation as this it is scarcely practicable to acknowledge the source of every extract; but for the use of such, however, my grateful thanks are due.

Figs. 25, 26, 28 and 29 are taken (by kind permission of the author and publishers) from Notter and Firth's *Hygiene*—Messrs. Longmans, Green & Co.

The blocks of Figs. 22 and 24 were lent by the courtesy of Messrs. Casella & Co.

The illustrations 49 to 60 inclusive were very kindly drawn for me by Mr. S. Sydenham, of Bath; and for the remainder I am myself responsible.

In conclusion, I must express a hope that this small work will prove of real use as an advanced compendium for those preparing for the D.P.H., rather than as a casual cram-book, of such questionable value to the student, and of such uselessness to the practitioner.

GILBERT E. BROOKE.

Bath.

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ESSENTIALS OF SANITARY SCIENCE

CHAPTER I

HYDROSTATICS

Matter exhibits itself under two forms—**Solid** and **Fluid.**

A **Solid** is a body which has a definite size and shape, the particles of which adhere to each other in such a manner as to offer resistance to forces tending to alter their shape.

A **Perfect Fluid** is a body the shape of which is altered by any force however small, and the particles of which move among themselves without friction.

Fluids present themselves to us under two forms—**Liquids** and **Gases.**

These three physical states can be well illustrated by a lump of ice—which has a definite shape and volume, and offers resistance to forces tending to alter the shape and volume. When the ice is melted we have a liquid the volume of which remains practically constant, while the shape adapts itself to the vessel in which it is contained. If the water be vaporized, the resulting gas-like substance is constant neither in volume nor shape.

A consideration of the properties of liquids is termed **Hydrostatics**; and of gases, **Pneumatics.**

HYDROSTATICS

A perfect liquid is an incompressible mass of indefinitely small particles which have no friction and no cohesion.

Liquids which offer resistance to forces tending to alter their shape are called **viscous,** *e. g.* tar, treacle, etc.

All known liquids are imperfect in that they are capable of some compression and exhibit viscosity.

Water, for example, can be diminished by about 1 per cent. in volume if subjected to a pressure of 3,000 lbs. per square inch.

Experimental proof of the compressibility of water is as follows :—

A narrow-necked glass flask is filled with water, and inverted with the mouth inserted into a cup of mercury. The flask and cup are then put within a strong glass cylinder fitted with a metal base and cap. This outer vessel is filled with water, the pressure of which is increased by the downward movement of a screw-piston working in the metal cap. As the pressure becomes very high the mercury will rise in the neck of the small inner vessel, thus showing that contraction of the water within it has occurred, and the amount of contraction can easily be measured.

Liquid pressure is estimated by the "**pressure at a point**"—that is, the pressure that would be exerted on a unit of area if the pressure over that unit area be assumed to be uniform with that on the smallest area containing the point.

There are three **Laws of Pressure.**

Law I.—The pressure of a fluid at rest is perpendicular to any surface with which it is in contact.

If a hollow sphere be filled with water, the internal pressure on different parts will vary, owing to the weight of the water; but the pressures will everywhere act at right angles to the surface.

If the pressure at any surface be uniform, then the

pressure on the whole surface can be deduced from that on a unit of area.

Law II.—The "pressure at any point" of a perfect fluid at rest is the same in all directions.

The proof of this law is as follows:—

Imagine a triangular prism filled with water, the ends of which are perpendicular to the sides. The forces at work are (1) the fluid pressures acting at right angles to its faces; and (2) the weight of the water.

With a very small prism, the pressure on any face may be considered as equal to the pressure at its middle point multiplied by the area of the face.

If the proportions remain the same while the prism is decreased in volume then the *areas* of the faces would diminish as the *square* of any edge, and the *weight* of the prism as the *cube* of any edge (*i. e.* when an edge is $\frac{1}{10}$th of its former length, the areas of the faces would be $\frac{1}{100}$th and the weight $\frac{1}{1000}$th of their former values). If a sufficiently small prism be taken its weight may thus be disregarded in comparison with the pressure on its faces.

Let a, b and c be the sides of the triangle formed by the end face, and let l be the length of the prism; then, since the side faces are rectangles, their areas are al, bl and cl.

Let the pressures at their middle points be P_1, P_2 and P_3. Then the total pressures on the side faces will be $P_1 \times al$, $P_2 \times bl$, and $P_3 \times cl$.

Now, since these three forces are in equilibrium, they must be proportional to the sides of the triangle to which they are perpendicular.

$$\therefore\ P_1 \times al : P_2 \times bl : P_3 \times cl :: a : b : c$$

$$\therefore\ P_1 \times a : P_2 \times b : P_3 \times c :: a : b : c$$

$$\therefore\ \frac{P_1 \times a}{a} = \frac{P_2 \times b}{b} = \frac{P_3 \times c}{c}$$

$$\therefore\ P_1 = P_2 = P_3$$

Law III.—Any pressure on the surface of a fluid is equally transmittted to all parts.

This law may be experimentally proved as follows:—

Take a vessel of any size or shape, having in its side a number of equal openings filled by pistons exactly filling them. Let a

certain pressure be applied to these pistons to keep them in equilibrium.

If now any additional pressure be applied to any one of the pistons, the *same* additional pressure will be found necessary for *all* the other pistons if they are to be kept in equilibrium.

The Safety Valve.

A weighted piston communicates with the interior of a boiler.

Since the internal pressure is equally transmitted to all parts, the piston will be lifted when this pressure is greater than that of the weight which was applied to the piston.

The weight is, of course, regulated according to the strength of the particular boiler.

The lifting of the piston is mechanically limited, and will only act through a certain distance sufficient to open a steam outlet and thus relieve the internal pressure.

The Hydrostatic or Bramah's Press.

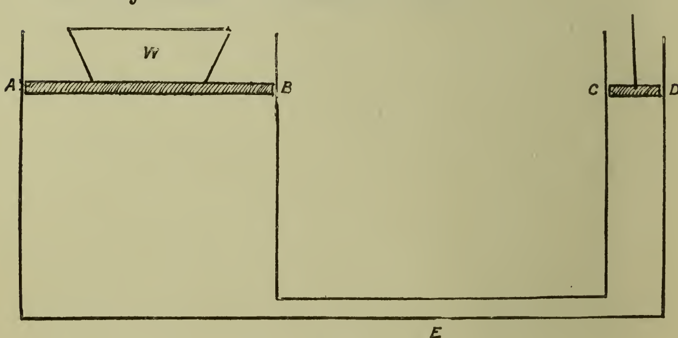

Fig. 1.

AB and CD are two water-tight pistons in the same horizontal plane, the vessel AED being filled with water.

If the area of the piston CD be one square inch, then any downward pressure on CD will exert the same pressure on every square inch throughout the whole vessel.

Thus, if the area of AB be 100 inches, the upward pressure thereon would be 100 times as great as on CD.

If A = area of large piston,
a = area of small piston,
P = pressure on large piston,
p = pressure on small piston,
then $P : p :: A : a$.

Example.—The area of the small piston is $\frac{1}{4}$ sq. in.; that of the large piston 1 sq. yd. If the weight on the large piston be 1 ton, what pressure must be applied to the small piston to maintain equilibrium?

$$A = 1 \text{ sq. yd.} = 9 \times 144 \text{ sq. ins.}$$
$$a = \tfrac{1}{4} \text{ sq. in., } P = 1 \text{ ton} = 20 \times 112 \text{ lbs.}$$
$$\therefore \frac{P}{p} = \frac{A}{a} \therefore \frac{20 \times 112}{p} = \frac{9 \times 144}{\frac{1}{4}}$$
$$\therefore P = \frac{20 \times 112 \times \frac{1}{4}}{9 \times 144}$$
$$= \frac{35}{81} \text{ lbs.}$$

By sufficiently diminishing the size of the smaller piston, an infinitely small pressure thereon could support an infinitely great weight on the larger piston.

This statement is known as the **Hydrostatic Paradox.**

The work done, however, when movement occurs, is the same. If movement, for example, takes place against an equilibrium of 1 lb. : 100 lbs., the smaller weight will be found to move through 100 times the distance moved through by the larger.

Dynamics of Heavy Fluids.

(1) **The pressure at any two points in the same horizontal plane are equal to one another.**

Theoretical proof.

Suppose AB to be any two points in the same horizontal plane, and a thin cylinder of liquid having vertical ends at A and B to become rigid, but no change to take place either in volume or weight. It will then remain in equilibrium; and the forces acting on it will be unchanged: they are—

1. Its weight acting vertically downwards.
2. Pressures on its curved surface all acting perpendicularly to the axis.
3. The horizontal pressures on the ends A and B.

These latter pressures must be equal whatever the area of A or B, otherwise the cylinder would move more towards A or B.

Therefore the pressure at A equals the pressure at B, which are two points in the same horizontal level.

(2) **Pressures are proportional to the depths below the surface, there being no external pressure.**

Theoretical proof.

Let A and B be two points in a vertical line, A at the surface of a liquid and B at some point within the liquid.

Imagine a thin cylinder of liquid with a vertical axis joining the points A and B, and having one horizontal base at A and the other at B.

Suppose this cylinder to become rigid, but no change to occur in volume or weight, it will then remain in equilibrium.

The forces acting on it will be—

1. Its weight acting vertically downwards.
2. The pressures on its curved surfaces, all perpendicular to the axis.
3. The upward pressure on the end B.

The weight of the cylinder will be supported by this upward pressure on the end B.

If the area at B be kept the same, the weight of AB must be proportional to its length. Therefore, if AB be made n times longer than before, the pressure supporting it at B must be n times as great, *i. e.* the pressures at different points are proportional to the depth of those points.

Experimental proof.

Take a piece of glass tubing. Hold a disc against one end, and insert in a beaker of water.

On pressing down the tube, the disc remains in position owing to the upward pressure of the water.

Now pour in some water at the upper end. The disc remains in position until the water in the tube reaches the level of the water outside.

This shows that the upward pressure on the disc is equal to the weight of the column of water in AB. Now the weight of this column varies as its length. Therefore the pressure at B varies as the depth.

(3) **The pressure exerted at any point in a vessel containing a heavy liquid at rest, is independent of the shape of the vessel.**

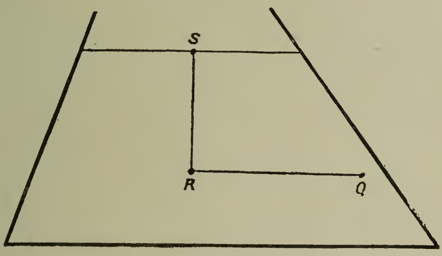

Fig. 2.

Theoretical proof.

Take an irregularly-shaped vessel, as, for instance, in the annexed cut.

Let Q be a point vertically beneath a point in one of the sides.

Let R be any point in the same horizontal plane as Q, but situated beneath the surface of the liquid.

Then the pressure at Q is equal to the pressure at R.

But the pressure at R depends on the length of RS.

Therefore the pressure at Q depends solely on the depth beneath the surface of the liquid, and is independent of the shape of the vessel in which the liquid is contained.

(4) **The surface of a heavy fluid at rest must be horizontal, the surface pressure being uniform.**

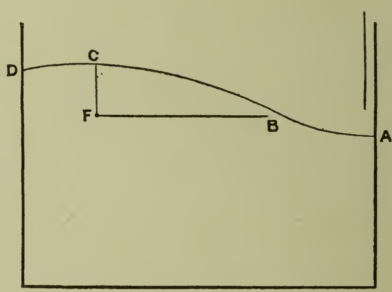

Fig. 3.

Theoretical proof.

If the surface be not horizontal, suppose it to be curved as ABCD.

Take two points in the same horizontal plane, one of which is on the surface (B) and the other beneath the surface of the liquid (F).

Now the pressure at B and F, being at two points in the same horizontal plane, is equal.

But the pressure at F is greater than the pressure at C.

Therefore the pressure at C is less than the pressure at B; which is absurd.

Therefore the surface cannot be other than horizontal.

(5) **If a body be immersed in a heavy fluid, the resultant of all the pressures exerted by the fluid on the body is a force acting upwards through the centre of gravity of the fluid displaced, and equal to the weight of the fluid displaced.**

This axiom is known as the **Principle of Archimedes.**

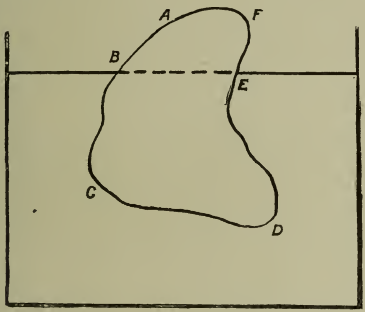

FIG. 4.

Theoretical proof.

Let ABCDEF be a solid body, having the portion BCDE immersed in a fluid.

Then the pressure at the various points of the immersed surface will depend on the depth of those points below the surface of the liquid.

That is, the resultant pressure on BCDE will be the same as if BCDE were itself composed of the fluid.

But, in that case, the portion BCDE would be supported by the surrounding fluid, and therefore the resultant of all the pressures must be equal to its weight, and would act vertically upwards through its centre of gravity.

Therefore the resultant pressure on the body is equal to the weight of the fluid displaced, and acts vertically upwards through the centre of gravity of the fluid displaced.

Experimental proof.

Let B be a solid heavy body.

Let A be a hollow vessel with a capacity exactly equal to the volume of B.

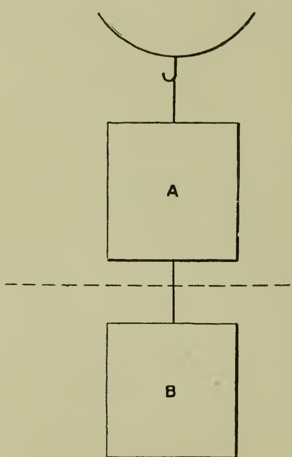

FIG. 5.

Suspend both from the pan of a balance as shown in the cut.

Weigh the two in air and note result.

Now lower B into some liquid until completely immersed, filling A with the same liquid.

Weigh again.

The total apparent weight will be found to be unaltered.

Therefore the gain in weight of A equals the apparent loss in weight of B.

That is, the gain in weight of A equals the resultant upward fluid pressure on B.

But the gain in weight of A equals the weight of fluid displaced by B.

Therefore the resultant upward fluid pressure on B equals the weight of fluid displaced by B.

MASS, DENSITY, WEIGHT, AND SPECIFIC GRAVITY.

The Mass of a body is the total amount of matter in it.

The unit of mass is the amount of matter in a unit volume of pure water at its maximum density, *i.e.* 4° C.

The Density of a body is the mass contained in unit volume.

The density of water at 4° C. is therefore called 1.

Let ρ be the density of a body of mass M, whose volume is V cub. ft.

Then

$$\begin{aligned} &\text{the mass of 1 cub. ft. is } \rho \\ &\quad ,, \quad ,, \quad 2 \quad ,, \quad ,, \quad 2\rho \\ \therefore\ &\text{the mass of V cub. ft. is } V\rho \\ \textit{i.e.}\quad & M = V\rho \\ &\textbf{mass} = \textbf{volume} \times \textbf{density.} \end{aligned}$$

The Weight of a body is the resultant of the forces caused by the attraction between its particles and the earth.

The weight of a body is usually ascertained by balancing it against the weight of a mass which is a known sub-multiple of the unit mass. For this purpose the "Beam Balance" is employed.

If we wish to compare the densities of different substances we compare the weight of a given volume with the weight of an equal volume of a standard substance, and the *ratio* so obtained we know as "specific gravity."

Specific Gravity is the weight of any volume of a substance compared with the weight of an equal volume of some standard substance under fixed conditions.

In the case of solids and liquids, the standard usually employed for the purposes of comparison is pure *water* at 4° C.

In the case of gases, the standard usually employed is *air* at 0° C., under a pressure of 30 ins. of mercury.

The following "water (at 4° C.) data" should be borne in mind:—

1 cub. ft.	weighs approx.		1000 oz.
1 gallon	,,	,,	10 lbs.
1 cub. centim.	,,	,,	1 gramme.

Specific gravities of solids and liquids are found by one or other of the three following methods:—

1. The hydrostatic balance.
2. The Nicholson's hydrometer.
3. The specific gravity flask.

1. **The Hydrostatic Balance.** (Applicable for solids and liquids.)

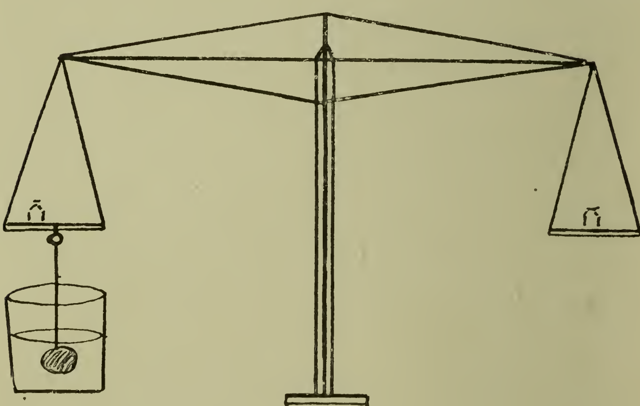

FIG. 6.

(a) *For insoluble solids heavier than water.*

Suspend the solid to the scale-pan, and weigh in air.

Then weigh it in distilled water. The loss of weight

when the solid is weighed in water will equal the weight of the water displaced. Then—

$$\text{Sp. gravity} = \frac{\text{Weight in air}}{\text{Loss of weight in water}}$$

$$S = \frac{W}{W - w}$$

(b) *For insoluble solids lighter than water.*

Weigh the solid A in air as before.
Then attach a heavy body, or "sinker," B, and weigh.
Then weigh with B submerged.
Then weigh with A and B submerged.

$$\text{Sp. gravity} = \frac{\text{Weight of A in air}}{\text{Loss of weight }(A+B) - \text{Loss of weight of B}}$$

(c) *For solids soluble in water.*

Some fluid of known or ascertained specific gravity should be chosen, in which the solid is not soluble. The specific gravity can then be readily found.

(d) *For liquids.*

A given solid is weighed in air, in water, and in the liquid to be determined, X. Then—

$$\frac{\text{Sp. gr. of water}}{\text{Sp. gr. of liquid X}} = \frac{\text{Loss of weight in water}}{\text{Loss of weight in liquid X}}$$

2. **Nicholson's Hydrometer.** (Applicable for liquids or solids.)

(a) *For solids.*

The hydrometer is placed in water and the scale-pan AB loaded with weights until the mark O exactly touches the surface of the water, the weights being recorded (W).

The solid is now put on the scale-pan AB and weights (w) added in addition until the mark O is at the surface of the water.

The weight of the solid will be $W - w$.

Now place the solid on the lower scale-pan CD and

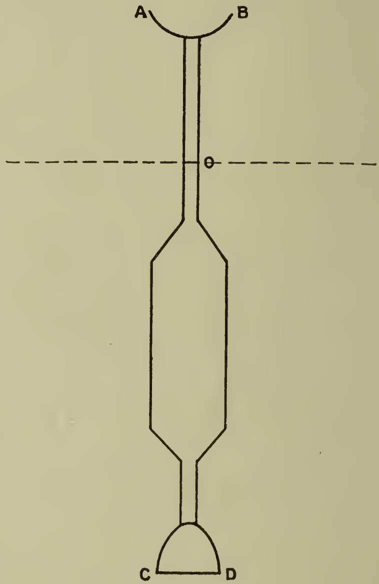

Fig. 7.

add weights (W′) on the upper scale-pan sufficient to sink the mark O to the water-level.

$$\text{Sp. gravity} = \frac{W - w}{W'}$$

(b) *For liquids.*

Weigh the hydrometer in air (W).

Then plunge in water and find the weight (w) which will bring O to the water-level.

Now plunge in the liquid to be tested. Add weights (w') till the mark O is at the water-level.

$$\text{Sp. gravity} = \frac{W + w'}{W + w}$$

NOTE.—Another type of hydrometer—the "Common Hydrometer," is frequently used for testing liquids, such as milk or urine.

In this instrument no weights are added. The weighted bulb at the end is permanently adjusted for an arbitrary scale above, and the depth to which the instrument sinks indicates the sp. gravity on the scale at the level of the liquid.

3. **The Specific Gravity Flask.** (Can be used for solids, such as powders, etc., for liquids, and is specially suitable for testing the specific gravities of small fragments of minerals and such-like.)

(a) *For powders insoluble in water.*

A portion of the powder is weighed, and the weight recorded (W).

This weighed amount is then replaced on the pan, and the specific gravity flask completely filled with water and placed on the same pan, and the whole weighed (w).

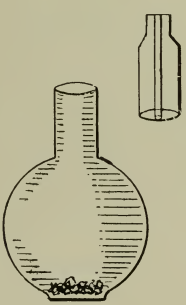

FIG. 8.

The stopper is then removed from the flask, the weighed powder is introduced and the stopper replaced.

It is then weighed again (w').

$$\frac{\text{Sp. gr. of powder}}{\text{Sp. gr. of water}} = \frac{W}{w - w'}$$

(b) *For powders soluble in water.*

A liquid should be used in which the powder is insoluble, *e.g.* alcohol for sugar.

(c) *For liquids.*

The weight of the dry flask is first ascertained (W). It is then filled entirely with water and the whole weighed (w). Next it is filled with the liquid to be tested and weighed (w').

$$\text{Sp. gravity} = \frac{w' - W}{w - W}$$

CAPILLARITY.

If a tube of glass, not exceeding $\frac{3}{4}$ in. in bore, be plunged vertically in a vessel of water and the water sucked up slightly and allowed to fall back, it will

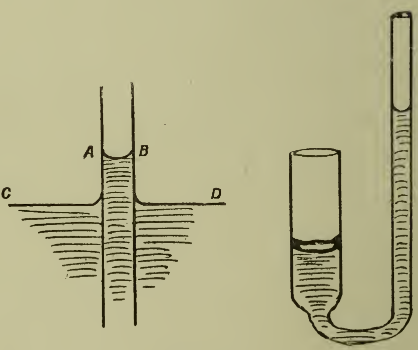

FIG. 9.

finally settle at a level AB above that of the liquid CD, and will have an upward concave surface.

Or if two tubes of differing bores be united in a U-shape and filled with water, a position of equilibrium

will be attained in which the level in the larger tube will be permanently below that in the smaller tube.

If the glass tube be plunged into mercury instead of water an exactly opposite condition will occur.

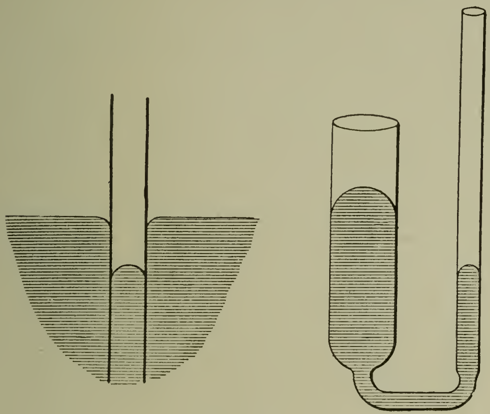

Fig. 10.

The phenomenon is capable of theoretical explanation. Gay-Lussac laid down some experimental **laws of capillary action.**

I. When a capillary tube is plunged into a liquid, the liquid is raised or depressed according as it wets or does not wet the tube.

II. For the same liquid, the elevation or depression varies inversely as the diameter of the tube.

III. The elevation or depression varies with the nature of the liquid and with the temperature, but is independent of the thickness of the tube.

Floating Bodies.

A body floating in a liquid is kept in equilibrium by its weight acting vertically downwards through its

centre of gravity, and the resultant of the fluid pressures.

But the resultant of the fluid pressures is equal to the weight of the fluid displaced, and acts vertically upwards through the centre of gravity of the fluid displaced.

As equilibrium is maintained, these two forces must be equal and opposite.

$\therefore$ (*a*) the weight of body = weight of fluid displaced,
and (*b*) the centres of gravity are in the same vertical line.

When a body of uniform density floats in a fluid, the volume of the part immersed is to the whole volume as the specific gravity of the body is to the specific gravity of the fluid.

Let V be volume of the body,
S be specific gravity of the body,
V_1 be volume of the part immersed (*i.e.* of the fluid displaced,
S_1 be specific gravity of the fluid.

Now—

Weight of body = weight of fluid displaced.

But—

Weight of body = its vol. × sp. gr. × weight of unit vol. of standard substance

And—

Weight of displaced fluid = its vol. × sp. gr. × weight of unit vol. of standard substance.

$$\therefore V_1 : V :: S : S_1$$

or

$$\frac{\text{Immersed vol}}{\text{Whole vol.}} = \frac{\text{Sp. gr. of body}}{\text{Sp. gr. of fluid}}$$

Example.—*A block of iron (sp. gr.* 7·8) *floats in mercury (sp. gr.* 13·6). *What portion of the iron will be immersed?*

Now $$\frac{\text{Vol. immersed}}{\text{Whole vol.}} = \frac{\text{Sp. gr. of iron}}{\text{Sp. gr. of Hg.}} = \frac{7{\cdot}8}{13{\cdot}6} = \frac{39}{68}$$

$$\therefore \text{Vol. immersed} = \frac{39}{68} \text{ of whole vol.}$$

CHAPTER II

PNEUMATICS

A perfect gas is an elastic fluid, of which a finite quantity may be made to fill any space, however great, by sufficiently reducing the pressure to which it is exposed.

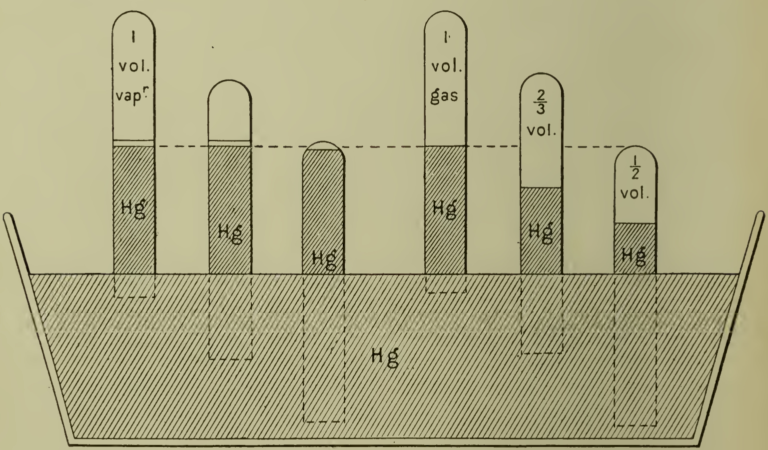

Fig. 11.

No known gases are perfect.
Gases should be distinguished from vapours.
A **vapour** is the gaseous state of a substance, which,

under normal conditions of temperature and pressure, is a liquid. Vaporisation is caused either by evaporation or ebullition.

Vapours do not obey the same laws as gases, as can be experimentally proved by the method shown in Fig. 11.

DIFFUSION OF GASES.

Diffusion is the property which gases and liquids have of mixing with each other, often in opposition to the laws of gravitation.

Law of diffusion of gases.

The rate of diffusion of gases varies inversely as the square roots of their densities.

If we fill a jar with CO_2, and cover the mouth with an inverted jar full of H, we should expect the latter (which is twenty-two times lighter than the CO_2) to remain floating above, like oil on water; whereas, after a short time the two gases will be found to be intimately mixed.

This intermixture takes place equally readily whether the gases are in direct contact or whether they are separated by means of any porous substance such as plaster of Paris or unglazed earthenware.

The law is capable of *experimental proof*, as follows :—

Let one end of a graduated glass tube containing 10 c.c. of H be covered with a porous plate, and the other end inserted in a basin of water. Let a bell jar filled with O be now held over the porous plate.

The water will immediately rise in the tube, showing that the H leaves the vessel more quickly than the O enters it.

When all the H has gone, only 2·5 c.c. of O will be found in the tube.

i.e. $$\frac{\text{The rate of diffusion of H}}{\text{The rate of diffusion of O}} = \frac{10}{2\cdot5} = \frac{4}{1}$$

But $$\frac{4}{1} = \frac{\sqrt{16}}{\sqrt{1}} = \frac{\sqrt{\text{Density of O}}}{\sqrt{\text{Density of H}}}$$

Therefore the rates of diffusion vary inversely as the square roots of their densities.

EXAMPLE 1.—*Find the vol. of* Cl *which diffuses in the same time as* 12 *c.c. of oxygen. The density of* Cl *being* 36 *and of* O, 16.

Now $$\frac{\text{Diff. of Cl}}{\text{Diff. of O}} = \frac{\sqrt{\text{density of O}}}{\sqrt{\text{density of Cl}}} = \frac{\sqrt{16}}{\sqrt{36}} = \frac{4}{6} = \frac{2}{3}$$

If therefore 2 c.c. of Cl diffuse in the same time as 3 c.c. of O, what vol. of Cl will diffuse in the same time as 12 c.c. of O ?

$$3 : 12 :: 2 : x$$
$$\therefore x = 8$$

Answer.—8 c.c. of Chlorine.

EXAMPLE 2.—*If* 4 *c.c. of a gas diffuse in the same time as* 3 *c.c. of Oxygen, find the density of the gas.*

i.e. $$\frac{\text{Rate of diff. of } x}{\text{Rate of diff. of O}} = \frac{4}{3}$$

But $$\frac{\text{Rate of diff. of } x}{\text{Rate of diff. of O}} = \frac{\sqrt{\text{density of O}}}{\sqrt{\text{density of } x}} = \frac{\sqrt{16}}{\sqrt{x}}$$

$$\therefore \frac{\sqrt{16}}{\sqrt{x}} = \frac{4}{3}$$
$$\therefore 4\sqrt{x} = 3\sqrt{16} = 12$$
$$\therefore \sqrt{x} = 3$$
$$\therefore x = 9$$

EXPANSION OF GASES.

Gases expand much more than either solids or liquids, and also expand more regularly.

All gases may be considered as having the same coefficient of expansion as air, any difference being exceedingly small.

The Coefficient of Expansion of a gas is the increase in volume of a unit volume when heated from 0° to 1° Centigrade.

It is found that this coefficient equals $\frac{1}{273}$ of the volume at 0° and is practically the same, whatever be the pressure to which the gas is exposed.

The Air Thermometer.

A thermometer in which air takes the place of mercury or alcohol has many *advantages.*

1. The nature of the contained gas is of no consequence, if it is dry, since the coefficient of expansion of different gases is the same.

2. It is very delicate, for the coefficient of expansion of gases is greater than that of liquids.

3. It can be used for very high and very low temperatures.

A small thread of mercury is generally used as an index.

The *disadvantage* is—that since the end of the tube must not be closed, a correction has to be made at each observation for changes in the atmospheric pressure.

Absolute temperature is the temperature reckoned from the absolute zero of the air thermometer.

A gas cooled below 0° C. loses $\frac{1}{273}$ of its volume for *each* degree below.

Theoretically, therefore, if a gas were cooled to $-273°$ C. it would have no volume at all, although probably it would have ceased to exist as a gas long before reaching that temperature.

This theoretical temperature of $-273°$ C. is called the "**absolute zero of the air thermometer.**"

Therefore—

Absolute	Centigrade	temperature	$= C + 273$
„	Fahrenheit	„	$= F + 459$
„	Réaumur	„	$= R + 218$

Laws of Expansion:—

I. **The volume of any mass of gas varies inversely as its pressure, the temperature being constant.**

Connecting pressure and volume; temperature constant.

Discovered by Hon. Robert *Boyle*, of Lismore, Ireland, in 1662; and independently by *Mariotte* in France, in 1679.

Called *Boyle and Mariotte's Law.*

II. **The volume of any mass of gas is proportional to the temperature reckoned from the absolute zero of the air thermometer, pressure being constant.**

Connecting volume and temperature; pressure constant.

Dalton's, or Charles', or Gay-Lussac's Law.

III. **The pressure of any mass of gas, whose volume is kept constant, is proportional to its temperature reckoned from the absolute zero of the air thermometer.**

Connecting pressure and temperature; volume constant.

IV. **The pressure of any mass of gas, whose temperature is kept constant, is proportional to its density.**

Connecting pressure and density; temperature constant.

As the volume of any mass of gas increases, its density diminishes. The density of a gas is inversely proportional to the volume assumed when expanding.

Hence, if d_1 be density when volume is V_1
and d_2 „ „ „ V_2
then

$$\frac{d_1}{d_2} = \frac{V_2}{V_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

If the temperature and pressure acting on a certain mass of gas be varied simultaneously, the volume ultimately assumed depends on the final pressure and temperature only, just as if the temperature were first altered and then the pressure, or vice-versâ.

If the *absolute temperature* of a mass of gas $= T_1$,

The pressure of the same mass P_1,

Its volume being V_1,

Then suppose the pressure to remain unchanged while the temperature changes to T_2, and let v be the new volume assumed,

Then, by Dalton's law—

$$\frac{v}{V_1} = \frac{T_2}{T_1}$$

$$\therefore v = \frac{V_1 T_2}{T_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

If this volume v be taken, while the temperature remains at T_2, and the pressure is altered to P_2, the new volume assumed being V_2,

Then, by Boyle's law—

$$\frac{V_2}{v} = \frac{P_1}{P_2}$$

$$\therefore v = \frac{V_2 P_2}{P_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (c)$$

Substituting this value for v in equation (b) we have—

$$\frac{V_2 P_2}{P_1} = \frac{V_1 T_2}{T_1}$$

$$\therefore \frac{V_1 P_1}{T_1} = \frac{V_2 P_2}{T_2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (d)$$

EXAMPLE 1.—*If* 1 *cub. ft. of air at* 0° *C., under a pressure of* 760 *mm. weighs* 1·2 *oz., what will a cub. ft. at* 27° *and under a pressure of* 600 *mm. weigh?*

First find what the cub. ft. of air would *measure* at 0° C. and 760 mm.

Working by equation (*d*)—

$$V_1 = 1 \qquad T_1 = 273 + 27 \qquad P_1 = 600$$
$$V_2 = ? \qquad T_2 = 273 \qquad P_2 = 760$$

$$\therefore \frac{600}{300} = \frac{V_2 \times 760}{273}$$

$$\therefore V_2 = \frac{2 \times 273}{760}$$

$$= \frac{273}{380}$$

$$\cdot 72 \text{ (approx.)}$$

Substituting now in equation (*a*) we have—

$$\frac{d_1}{1{\cdot}2} = \frac{\cdot 72}{1}$$

$$\therefore d_1 = \cdot 72 \times 1{\cdot}2$$

Answer. Approximately, ·864 oz.

Example 2.—*A certain gas occupies* 879 *cub. ft. at a temp. of* 20° *C. under a pressure of* 29 *in. of mercury; what will be its vol. at a temp. of* 40° *C., under a pressure of* 30 *in. mercury?*

Working by equation (*d*) we have—

$$V_1 = 879 \qquad T_1 = 273 + 20 \qquad P_1 = 29$$
$$V_2 = \qquad T_2 = 273 + 40 \qquad P_2 = 30$$

$$\therefore \frac{879 \times 20}{293} = \frac{V_2 \times 30}{313}$$

$$\therefore V_2 = \frac{879 \times 20 \times 313}{293 \times 30}$$

Answer. 907·7 cubic feet.

Atmospheric Pressure.

The atmosphere exerts an approximate pressure of about 14·7 lbs. on every square inch of surfaces with which it is in contact. As this is an established condition, we are unconscious of it unless subjected to any serious alteration. Thus at high altitudes, on mountains, or in balloons, the diminished pressure causes

rupture of the smaller vessels, bleeding of ears, nose, eyes, etc., accompanied by much discomfort.

The first actual measurement of the atmospheric pressure was by *Torricelli* in 1643, resulting in the invention of the mercurial **Barometer.**

The construction of the barometer is as follows—

A tube, AB, 3 feet long and closed at one end, is filled with mercury. The open end B is then temporarily closed and the mouth of the inverted tube plunged into a vessel of mercury.

On opening the end B the mercury will be seen to sink till its surface is about 30 inches above the surface of the mercury in the vessel (760 mm.).

This column can be furnished with a scale for reading the exact height. That this height varies as the atmospheric pressure, is proved as follows—

Let F be a point within the tube in the same horizontal plane as the surface of the mercury in the vessel. There is no pressure on the surface at E, therefore the pressure at F varies as the length of EF. But the pressure at F = the pressure at C, and the pressure at C is the atmospheric pressure.

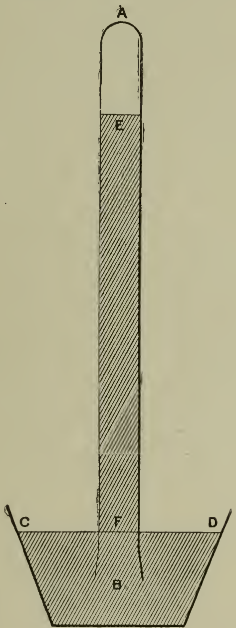

Fig. 12.

Therefore the length of EF varies as the atmospheric pressure.

The space above the mercury is practically a vacuum, and is called the **Torricellian Vacuum.**

The shape and inclination of the barometer is of no

consequence, but, if not vertical, the *length* of the mercury column will not vary as the pressure, the *vertical height* alone being of consequence.

Other liquids than mercury may be used to make a barometer provided that a sufficiently long tube is taken.

The **Water Barometer** is 13·6 times as high as the column of mercury, and thus is 13·6 times as sensitive. The objection is, that evaporation above the water surface prevents a good vacuum being secured.

This can be partly obviated by using a **Glycerine Barometer**, with which a fair vacuum can be obtained; and, as its specific gravity is 1·26, it is more than 10 times as sensitive as mercury.

To compare the weights of barometers filled with different liquids.

Let h_1 be the height of the mercury barometer,
h_2 ,, ,, ,, other barometer,
S_1 ,, sp. gr. of the mercury,
S_2 ,, ,, ,, other liquid.

Then, as the pressure at a point exerted by both columns is the same,

$$\therefore \frac{h_2}{h_1} = \frac{S_1}{S_2} \therefore h_2 = h_1 \times \frac{S_1}{S_2}$$

But the sp. gr. of mercury = 13·6,

$$\therefore \text{weight of any barometer} = \frac{\text{weight of Hg barometer} \times 13{\cdot}6}{\text{sp. gr. of the liquid}}$$

In construction of a mercurial barometer it is important to notice—

(*a*) That the mercury is dry.

(*b*) That no air bubbles are left in the mercury.

(N. B.— ∴ it should be boiled in the tube before inverting it.)

Corrections have to be made for capillarity, temperature, and altitude.

The **Aneroid Barometer** (*ἀ* = without, and *νηρος* = moist) is devoid of liquid. It consists of an hermetically sealed metal box, exhausted of air, the sides of which are kept apart by a metal spring. The cover moves in or out according to atmospheric pressure; and such movements are communicated to a graduated dial-hand.

Experimental Proof of Boyle's Law.

Take a bent tube, EA, closed at A. Insert mercury until the level BC is the same in both arms.

Pour in more mercury.

When the surface in the long arm is at E, let that in the shorter be at D.

Let F be in the same horizontal superficies as D. Let the vertical distance EF = h. Let the height of barometer (during experiment) = H.

$$\frac{H}{H+h} = \frac{\text{Pressure on air in AC}}{\text{Pressure on air in AD}}$$

But if we measure the volumes of air in AD and AC we find—

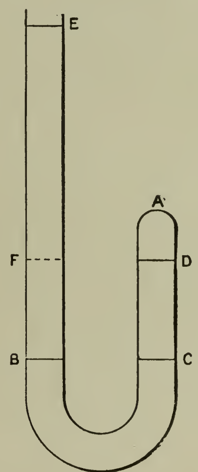

FIG. 13.

$$\frac{H}{H+h} = \frac{\text{Vol. of air in AD}}{\text{Vol. of air in AC}}$$

$$\therefore \frac{\text{Press. in AC}}{\text{Press. in AD}} = \frac{\text{Vol. in AD}}{\text{Vol. in AC}}$$

That is—the pressure varies inversely as the volume.

THE SIPHON.

The Siphon is a bent tube open at both ends, and used to bring liquids over some obstacle such as the side of a vessel.

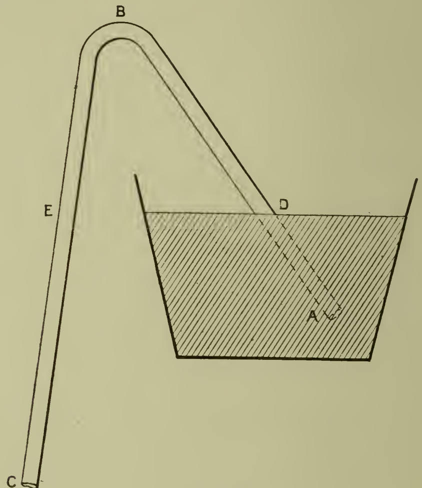

FIG. 14.

Let ABC be a bent tube filled with the same liquid as that which is contained in the vessel to be emptied.

Insert the tube, placing the end A below the surface of the liquid in the vessel, the end C being outside the vessel and below the surface plane.

On opening the ends of the tube water will flow and continue to flow out of the vessel.

The pressures at D and E are the same, being points in the same horizontal plane. But the pressure at D is that of the atmosphere. This pressure will therefore support the portion of the liquid DBE, unless the height of B above the surface is greater than the barometric height.

The downward pressure at C, however, is greater than the pressure at E by the weight of the column of liquid EC; and, when the end C is opened, the atmospheric pressure is consequently unable to sustain the liquid within, which will continue to flow until the level of the liquid in the vessel falls below either A or C.

AIR PUMPS.

Hawksbee's Air Pump.

Valves at A, B, C and D open upwards. The piston rods act in mechanical connection with alternate strokes.

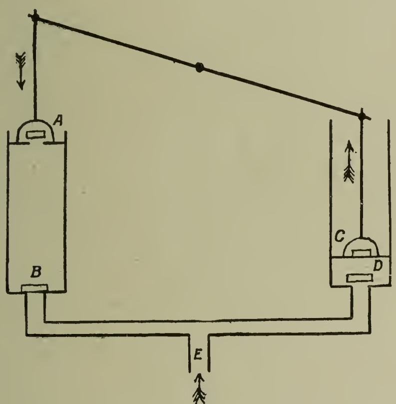

FIG. 15.

The air to be exhausted comes through E.

The action is automatic and alternate, and is sufficiently explained by the diagram.

Smeaton's Air Pump.

The three valves at A, B, and C all open upwards.

The action is the same as in Hawksbee's pump—

except that there is but one cylinder, and there is an additional valve at A, the effect of which is to remove the pressure of the atmosphere from the top of the piston during part of a stroke.

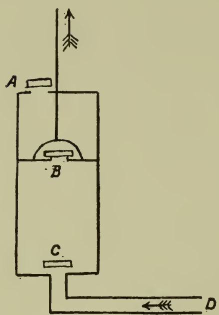

FIG. 16.

In problems connected with the foregoing air pumps, it should be remembered that the densities are inversely as the volumes.

Let D_1, D_2, . . . D^n be the density after the 1st, 2nd, and nth stroke,
V = volume of receiver and pipe,
V_1 = volume of barrel between highest and lowest positions of piston,
D = original density of air,

Then $$\frac{D_1}{D} = \frac{V}{V + V_1} \text{ and } D_n = D\left(\frac{V}{V + V_1}\right)^n$$

The Condenser.

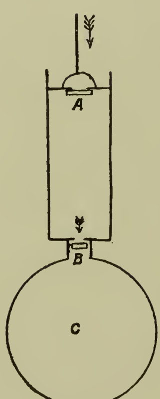

FIG. 17.

The action of this machine is to mechanically increase the internal air pressure in any vessel.

A bicycle pump and tyre valve is a familiar example of such apparatus.

The valves at A and B open downwards on the upward stroke, the cylinder fills with air through the valve A, and the valve B automatically closes owing to the increased pressure in C.

On the downward stroke the cylinder air is forced into the receiver.

Let V = volume of receiver,
V_1 = volume of cylinder between highest and lowest position of piston,
D = original density of air,
D_1, D_2, . . . D_n = density after 1st, 2nd, and nth stroke,

Then $$\frac{D_1}{D} = \frac{V + V_1}{V}$$

and $$\frac{D_n}{D} = \frac{V + n . V_1}{V}$$

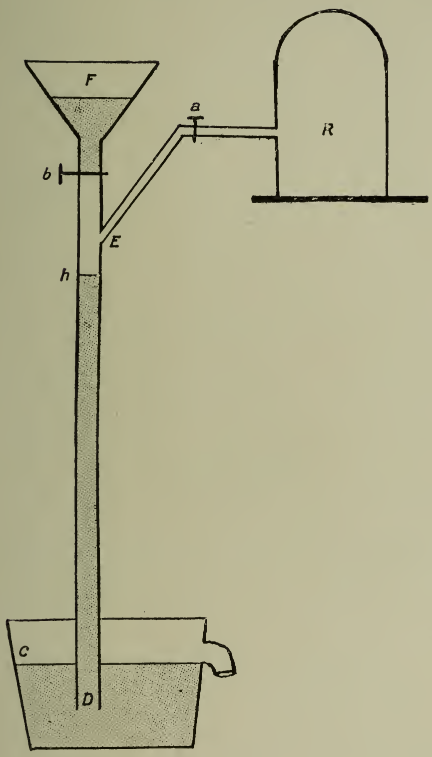

FIG. 18.

The valves of air pumps are usually made of pieces of oiled silk.

All these pumps, such as Hawksbee's and Smeaton's, which rely on the principle of valves, do not get at all a

perfect vacuum. In order to obtain a better result, a valveless air pump should be used, such as **Sprengel's Air Pump.**

A tube, FD, 46 inches long, with a funnel on the upper end, is connected with a receiver R by a tube entering at E.

There are stop-cocks at *a* and *b*.

The point E should be more than 30 inches from D.

The tap *a* is closed. The vessel C is filled with mercury; and mercury is poured into the funnel F.

If the cock *b* is closed now, the mercury will fall to the level *h*, thus making a barometer, with a vacuum above the column of mercury.

On opening cock *a* the vacuum will be replaced by air from the receiver R.

The tap *a* is closed again and the whole process repeated.

Each operation removes more air from R until an almost perfect vacuum is produced.

In practice, however, it is not necessary to keep opening and shutting the cocks. They are left permanently open, and a continuous flow of mercury is carried out.

When the vacuum is nearly perfect, no air bubbles pass into the tube to break the fall of mercury on to the top of the barometer column, and thus a loud noise is heard.

Water Pumps.

Common or Suction Pump.

Valves at D and B open upwards.

On raising the piston, the air from the pipe now fills pipe and cylinder, and this reduced pressure allows the atmospheric pressure on the surface E to force some water up the tube.

As the piston descends the valve at B closes, and air from the cylinder passes out of the valve D.

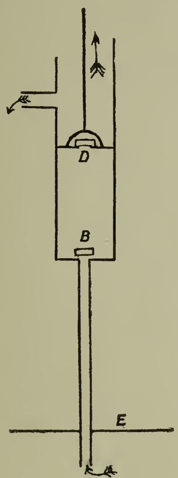

Fig. 19.

On repeating the stroke the water rises till it flows through the valve B. On the next downward thrust the water passes through D, and is then lifted and discharged through A.

Since the water is raised to B by the pressure of the atmosphere alone, the distance B E must not be greater than the height of the water barometer.

The Force Pump.

Two valves, at B and F, open upwards.

As the piston ascends, F is closed by atmospheric pressure; B opens, and the diminished pressure of air in pipe and cylinder admits of the atmospheric pressure on E, forcing water up the pipe.

When it has filled the cylinder, and the piston next descends, the valve B automatically closes, and the water is forced through **F**, which afterwards closes and prevents its subsequent return.

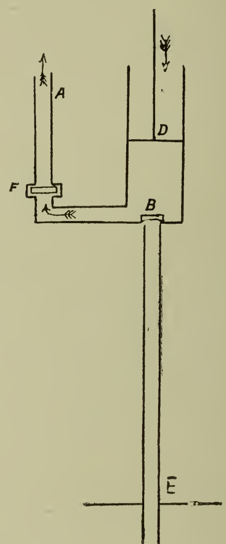

Fig. 20.

B E must not be greater than the height of the water barometer (34 feet).

The Fire Engine

consists of two force-pumps acting alternately, the discharge pipes of which open into an **air chamber.**

The valve at B opens upwards to admit the water forced in by the pump.

The ultimate discharge pipe, K H, ends in the centre

of the chamber. As the water is forced in from the pump, the air it displaces will pass up H K until the water level reaches H.

The next stroke will force the water, say, to G.

The air above it is now unable to escape; its volume

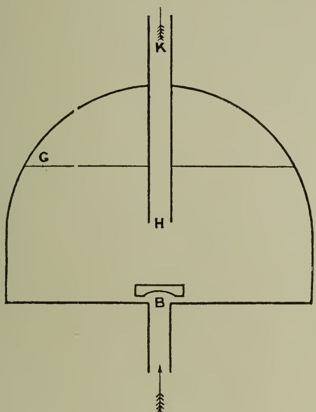

FIG. 21.

diminishes, and, therefore, its pressure on the surface of the water is increased.

When the inrush of water ceases, the back pressure closes the valve B, but the pressure at the surface of the water at G forces some of the water up the pipe H K, and thus a continuous, instead of an intermittent, flow is maintained.

CHAPTER III

HEAT

THE word "**Heat**" is used in Science to denote **one form of the energy possessed by the molecules of a body; the molecules being supposed to be in more or less rapid vibration.**

The *effects* of the application of heat to bodies are:—

(*a*) Change in temperature.
(*b*) Change of condition.
(*c*) Alteration in volume ($\therefore$ in density).
(*d*) Change in chemical composition.

Temperature may be defined as **the thermal condition of a body with reference to its power of communicating heat to other bodies, or receiving heat from them.**

A body is said to be at a higher temperature than another body if, after being placed in contact, it loses heat while the second body gains it.

Most bodies expand on being heated, and such expansion will form a practical arbitrary method of measuring temperature.

A **thermometer is an instrument for measuring temperature.**

Certain substances are better suited than others for thermometrical purposes. Solids are not used because their expansion is too small. Gases are too much influenced by changes of pressure, diffusion, etc., although

for certain purposes (such as very high temperatures) an air thermometer is useful. Liquids are, therefore, best adapted for thermometry.

Water is inconvenient, owing to the small range of temperature between the freezing and boiling points.

Alcohol boils at a lower temperature than water, and therefore its use is restricted, although (since it does not freeze at any known temperature) it is used for minimum thermometers and very low temperatures.

Mercury is usually employed, for the following reasons:—

(*a*) It can usually be obtained pure.
(*b*) Its boiling point is high (357° C.).
(*c*) Its freezing-point is low (−39° C.).
(*d*) It has a uniform expansion over a large range of temperature.
(*e*) Its specific heat is small, thus it does not absorb much heat from the body with which it is in contact.
(*f*) Its conductivity is great, so that it quickly assumes the temperature of anything in which it is immersed.
(*g*) It does not soil the glass.

Delicacy of a thermometer.

(1) A large bulb and small tube are necessary to register *small* changes of temperature.
(2) A small bulb is required if *quick* variations are needed.

Construction of the Thermometer.

A piece of glass tubing of fine and *uniform* bore, and about 12 inches long, is closed at one end and blown into a bulb.

The other end is now bent at an acute angle about one and a half inches from the end.

Some mercury is heated and put in a small beaker.

The open end of the thermometer tube is held beneath the surface of the mercury, and at the same time a spirit lamp is held beneath the bulb.

The air in the bulb expands and escapes by bubbling through the mercury.

The spirit lamp is removed, and as the air within cools and contracts, atmospheric pressure forces some of the hot mercury into the tube.

The process is repeated until the mercury completely fills the tube.

The bulb and lower part of the tube are now put in some liquid, and heated above the highest temperature at which it is intended ever to be used, when some of the mercury of course overflows.

The tube is softened by heat just below the bend, and a blow-pipe flame is brought to bear on it, when the end is drawn out and sealed up.

Graduation of the Thermometer.

This consists of sub-dividing the interval between what are called the two "**Fixed Points,**" i.e. the temperature of melting ice, and that of the steam issuing from water boiling at a constant atmospheric pressure.

There are three current scales of graduation between these two fixed points.

The most unscientific of these is, of course (*vide* our coinage and weights and measures), the one in common use in this country, viz., the **Fahrenheit scale.** This was introduced by Fahrenheit of Dantzig in 1714. A mixture of snow and ice was supposed by him to indicate the lowest attainable temperature, and this point was taken as his zero. In such a thermometer the temperature of melting ice is 32°, and of steam 210.

The second scale used in several European countries for medical and domestic purposes is that of **Réaumur,**

in which the melting-ice point is zero, but the boiling point is 80°.

For the most scientific scale—the **Centigrade**—we are indebted to Celsius. Here the temperature of melting ice is marked as zero, and that of streaming steam at 100.

The **equations connecting the three systems** are—

$$\frac{F - 32}{9} = \frac{C}{5} = \frac{R}{4}$$

Air Thermometers.

The expansion of gas is uniform, and is about twenty times as great as that of mercury. A simple form is **Leslie's Differential Thermometer**, consisting of two bulbs containing air, connected by a bent glass tube, in which is an index of non-volatile liquid, usually coloured sulphuric acid.

Slight differences of temperature are by this means easily *indicated*, but not measured.

Various kinds of thermometers are used to measure very high temperatures, and are called **Pyrometers**, such as the "porcelain air flask"; or a platinum wire, of which the temperature is measured by changes in its electrical resistance.

Expansion of Solids.

Most solids (except baked clay, stretched india-rubber, and a few other substances) expand when their temperature is raised.

(*a*) The **Co-efficient of linear expansion** is the increase in length of a unit of length of a body when its temperature is raised from 0° to 1° C.

(*b*) The **Co-efficient of superficial expansion** is the increase in area of a unit of the surface when its temperature is raised from 0° to 1° C.

(*c*) The **Co-efficient of cubical expansion** is the increase in volume of a unit of volume of a body when its temperature is raised from 0° to 1° C.

(NOTE.—*b* is approx. twice, and *c* three times the value of *a*.)

To find the coefficient of linear expansion.

Let k be the coefficient.

Then the increase in length of a unit of the body when heated from 0° to 1° C. is k.

Therefore the increase in length of l units if heated through $t°$ equals $l \times t \times k$.

Thus—

Total linear expansion $= l \times t \times k$,
,, superficial ,, $= a \times t \times 2\,k$,
,, cubical ,, $= v \times t \times 3\,k$,

where a and v are areas and volumes at 0° C.

Example.

An iron girder is 40 feet long at 0° C., what will be its length at 50° C.?

C. of L.E. = 0·000012.

Now, $l = 40$ feet, $t = 50°$ C., $k = 0·000012$.

∴ L.E. = 40 × 50 × 0·000012 feet
= 0·0024 feet.

∴ length at 50° C. = 40 + 0·0024 feet
= 40·0024 feet.

The *linear expansion* can be determined by **Laplace's instrument.** A bar of the substance is placed horizontally in a trough containing oil. One end of the bar rests against a fixed point; the free end rests against a lever, the movements of which are communicated to a graduated dial.

The oil in the trough is heated and the consequent expansion of the metal is noted.

EXPANSION OF LIQUIDS.

Not only the liquid itself, but also the vessel which

holds it, contracts and expands with changes of temperature.

We must distinguish between the *absolute expansion* which is the real increase in volume, and the *apparent expansion*, which is the absolute expansion diminished by the expansion of the vessel which contains the liquid.

The apparent expansion of liquids is determined by an instrument termed a **weight thermometer**, which consists of a bulb with a narrow neck. The weight of this, filled with the liquid, is determined at 0° C. and also at a temperature t°.

$$\frac{\text{The wt. of the overflow}}{\text{2nd wt. of liquid} \times t} = \text{coeffit. of expansion}$$

Expansion of water (Hope's experiment).

A cylinder is filled with pure warm water, and round the middle is placed a freezing mixture.

Thermometers are inserted near the top and bottom.

The water cools, and it is found that the lower thermometer registers less than the upper.

On reaching 4° C. this lower thermometer remains stationary but the upper continues to fall until it reaches 0° C., when ice is formed.

Thus whatever the temperature of the water, that portion at 4° C. will sink, proving that water is most contracted at that temperature. This we express by saying that the **maximum density of water is 4° C.** The physical consequences are very important.

A lake is cooled by the low atmospheric temperature on the surface. This cold water keeps on sinking and the warmer water from below rising, to become cooled in its turn, until the whole is at 4° C.; after which the surface water, which is cooled further, does not sink but becomes frozen. Thus fish, which can live at 4° C., are protected in deep water even in the severest frost.

In the act of freezing the water expands by about $\frac{1}{10}$ of its volume, and therefore ice floats.

If it contracted when solidifying, all lakes and rivers would freeze throughout and not melt even in summer.

The expansion of forming ice accounts for the bursting of water pipes during a winter frost.

The **maximum density of sea water is $-2{\cdot}5^\circ$ C.** The surface water therefore continues to sink when cooled until the temperature of the whole is $-2{\cdot}5^\circ$ C., when salt is deposited and fresh-water ice formed on the surface.

Expansion of Gases.

(*See* Chapter II., Pneumatics.)

Calorimetry (measurement of heat).

A thermal unit (or caloric) is the amount of heat required to raise 1 gramme of pure water from 0° to 1° C.

Experiment will show us that equal masses of different substances require a very different number of thermal units to raise their temperature through the same number of degrees. The quantity in each case depends upon a certain property termed its *specific heat.*

The specific heat of a substance is the number of thermal units required to raise its temperature by 1° C., as compared with the number of thermal units required to raise an equal weight of water from 0° to 1° C.

The **capacity for heat** of a body is the number of thermal units required to raise its temperature 1° C.

We determine the sp. heat of a body by one of three different ways—

(*a*) method by mixture,
(*b*) „ fusion,
(*c*) „ cooling.

(*a*) *Method by mixture.*

Plunge a hot body of temperature t, sp. heat S_1 and weight w_1 into a cold liquid of temperature t^2, sp. heat S_2 and weight w_2.

After a time the liquid and body will both be at the same temperature T.

Then the temperature of the hot body will fall $(t_1 - T)$ degrees.

$\therefore$ Heat given out by the hot body $= S_1W_1(t_1 - T)$

The temperature of the liquid will rise $(T - t_2)$ degrees.

$\therefore$ Heat absorbed by liquid $= S_2W_2(T - t_2)$

But the final temperatures are equal.

$$\therefore S_1W_1(t_1 - T) = S_2W_2(T - t_2)$$

$$\therefore S_1 = \frac{S_2W_2(T - t_2)}{W_1(t_1 - T)}$$

(*b*) *Method by fusion.*

In which some form of *calorimeter* is employed—usually either *Black's*, *Laplace's* or *Bunsen's*, which depend on the melting of ice by a heated body.

(*c*) *Method by cooling.*

In which is determined the length of time which equal weights of bodies will take to cool—these rates varying in the same ratio as their specific heats.

Change of Condition.

On heating a fusible solid it expands until the temperature reaches the **fusing point**, when it begins to liquefy. While the liquefaction is proceeding, the temperature does not rise above the fusing point, however much it is heated, since the heat during that time is expended in doing work such as overcoming molecular attraction, etc. The heat so expanded is termed *Latent Heat.*

The Latent Heat of a substance is the heat absorbed or given out by a unit weight of that substance when changing its physical state, without alteration of temperature.

If a lb. of ice at 0° be mixed with a lb. of water at 79°, the result will be 2 lbs. of water at 0° C.; but if a lb. of *water* at 0° be mixed with a lb. of water at 79° C., the result will be 2 lbs. of water at 39·5.

Thus all the heat expended by a lb. of water during the fall of temperature from 79° to 0° is devoted to the work of liquefying the lb. of ice.

Thus the *latent heat of fusion* of ice is said to be 79 thermal units.

The **laws of fusion** are—

I. Every substance begins to melt at a definite temperature, when the pressure is constant.

II. The temperature is constant from the time it begins to melt, until fusion is complete.

The apparent disappearance of heat during the change of physical state is due to the work done in changing that state.

It can be shown that a definite amount of work is done by each thermal unit which has disappeared.

This work is expressed by the term, **the Mechanical Equivalent of Heat,** worked out by *Joule.*

He found that the temperature of 1 lb. of water could be raised through 1° C. by means of the work done by a weight of 1 lb. falling through a distance of 1390 feet,

i.e. J = 1390 foot pounds.

Evaporation.

Evaporation is the production of a vapour at the surface of a liquid.

Liquids which can be vaporised are called *volatile.*

If a little volatile liquid is introduced into a Torricellian vacuum, it vaporises, and the mercury is depressed.

If more liquid is then introduced, an amount is soon reached above which no more liquid will evaporate, however much may be introduced. The vapour is then said to be *saturated.*

The pressure of a saturated vapour is independent of external pressure, but dependent upon its temperature; thus, in hot, dry weather there will be more vapour in the atmosphere than in cold, wet weather.

Certain liquids, such as the heavy oils, cannot be vaporised without decomposition.

The **laws of evaporation** are—

I. There is a maximum pressure for each temperature.
II. The pressure rises with the temperature.
III. The pressure varies with the nature of the liquid.
IV. The pressure is independent of the medium.

Evaporation will continue from the surface of a volatile liquid at a given temperature, until the pressure exerted upon it by its own vapour is equal to that atmospheric pressure which would determine the boiling point of the liquid at that temperature.

The rate of evaporation is influenced by—

(*a*) The temperature.
(*b*) The surface area.
(*c*) The amount of vapour already in the air.
(*d*) The rapidity of air renewal.

Ebullition.

Ebullition is the production of bubbles of vapour in the body of the liquid itself.

The attainment of such a crisis is known as "*the boiling point.*"

A liquid boils when the pressure of its vapour becomes equal to the pressure to which it is exposed.

This dependence of a boiling point on pressure is well shown by "*Franklin's experiment*": Water is boiled in a flask (narrow-necked), and tightly corked, while containing only water and steam.

Although removed from the flame, the water can be made to boil again by pouring cold water on the neck of the vessel, showing that the water boils at a lower temperature than normal, owing to the reduced pressure of the contracted vapour.

The pressure of the atmosphere diminishes the higher we ascend.

At the top of Mont Blanc water would boil at about 85° C., instead of 100°, owing to the diminished pressure.

The boiling point is sometimes used to determine the height of mountains, the apparatus being called an **hypsometer.**

Spheroidal condition.

If a volatile liquid be sprinkled on a very hot metal surface, it rolls about in little globules, neither being itself vaporised nor wetting the metal.

This phenomenon is possibly due to the fact that when the liquid touches the metal a small portion is vaporised and forms a cushion.

The **laws of ebullition** are—

I. Every liquid has a definite boiling point for a definite pressure.

II. A liquid boils when the maximum pressure of its vapour equals the atmospheric pressure.

III. The temperature rises up to boiling point, and is then stationary until all the liquid has evaporated.

"*Papin's Digester*" is a strong vessel partly filled with water, and having its lid tightly closed. As the steam cannot escape, the temperature of the liquid can be raised far above 100° C., and thus can extract gelatin from bones, etc.

Transmission of Heat.

The reception or bestowal of heat by any body takes place in one of three ways—(*a*) Conduction, (*b*) Convection, or (*c*) Radiation.

A vessel of water over a gas flame will furnish an example of all these.

The bottom layer will receive its heat from the flame by *conduction* through the substance of the vessel.

The heated water then rises to the surface, which becomes heated by *convection*. If the hand do not touch, but be held near the vessel, the heat felt is transmitted by *radiation*.

Conduction.

Conduction is the transmission of heat from one part of a body to another by means of the heating of the intermediate particles.

As a rule metals are good conductors. Liquids, gases, wood, wool, etc., are bad conductors.

The Thermal Conductivity of a substance is the number of thermal units which will pass between two opposite faces of a cube one centimetre in thickness, in a second of time, the two faces being kept at a constant difference of one degree of temperature.

(Note.—This is sometimes miscalled "*Specific* thermal conductivity"—which would of course imply that it was a ratio, which it is not.)

$$\text{The number of thermal units} = \text{area} \times \frac{1}{\text{thickness}}$$

$\times$ time $\times$ difference in temperature between the two sides $\times$ k.

CONVECTION.

Convection is the carrying of heat by matter.

It depends on—

(*a*) The expansion of bodies when heated.

(*b*) The action of gravity. Nearly all ocean currents and winds are convection currents.

The principle is relied on in the heating of buildings by hot-water pipes. The water is heated at the base and rises in one branch while the cooler water returns to the furnace by another.

RADIATION.

Radiation is the transmission of heat from one body to another at a distance, without heating the intervening medium.

The sun's heat is thus communicated to the earth without a corresponding heating of the atmosphere. All bodies emit radiant heat, and, if heated sufficiently, become obvious to the eye. The same radiation which, when we become aware of it by the eye, we call light, when we detect it by a thermometer or by the sensation of heat, we call heat.

Radiant heat, like light, is propagated in a straight line, can travel through a medium without heating it, and is reflected and refracted.

Laws of radiation are—

I. Radiation takes place in all directions round a body.
II. In a homogeneous medium radiation takes place in straight lines.
III. It is propagated in a vacuum as well as in air.
IV. The intensity is inversely as the square of the distance from the source.
V. The angle of incidence is equal to the angle of

reflection, and the reflected and incident rays are in the same plane.

Prevost's Theory of Exchanges—

Bodies whose temperature remains constant are radiating as much heat as they receive.

Some bodies are very transparent to dark-heat rays, and are called **diathermanous,** *e.g.* rock-salt, ice.

Other bodies are opaque to the dark-heat rays, although transparent to the shorter waves causing light as well as heat. These are called **athermanous,** *e.g.* glass.

In the case of *green-houses,* the dark-heat rays do not penetrate the athermanous glass, but the shorter light and heat rays pass in, and warm the bodies by which they are absorbed. These contents radiate this heat, but in the form of the long wave lengths of dark heat to which the glass is opaque. The heat is thus stored up in the building and can only slowly escape by conduction.

Fire-screens can with advantage be made of glass, which will cut off the dark-heat rays which an ordinary fire mostly radiates.

Moist air, like glass, is rather opaque to the dark-heat rays. The aqueous vapour of the atmosphere therefore serves to store up much heat and tends to render the temperature equable. In dry desert climates, such as the Sahara, the absence of any atmospheric athermanous screen will allow great heat during the day, and cold (from rapid loss of heat) during the night.

The radiating power of substances is much affected by its surface.

Good reflectors are bad radiators and bad absorbers.

Good absorbers are good radiators.

A kettle should therefore be black on the bottom to absorb the heat readily; but it should be polished on the top and sides so as to minimise the radiation of heat from them.

CHAPTER IV

METEOROLOGY

Natural Phenomena.

I. Winds.

Wind is a movement of the atmosphere. In England the *average velocity* of the wind is about 8 miles an hour, and the English equinoctial gales rarely exceed 40 to 45 miles an hour.

In England the *most prevalent winds* are the S.W. and the W., moist and warm winds resulting from the Gulf Stream.

Next most common are N. and E.; then S.E.; and N.E. least prevalent. The E. and N.E. winds coming from Northern Europe are cool and dry.

Trade winds occur in the Pacific, Atlantic and Southern part of the Indian Ocean, mostly between the tropics of Cancer and Capricorn. To the N. of the Equator the prevailing direction of these trade winds is N.E.; while to the South of the Equator they are S.E. They are caused by the perpendicular equatorial rays of the sun, which heat the air and thus cause expansion and diminished pressure. The air in consequence rises, and the cooler air from N. and S. flows in to supply its place.

At the Equator the rotational velocity of the earth is about 1000 miles per hour in an easterly direction, thus giving an apparent N.E. and S.E. direction to the N. and S. winds.

Other winds are *seasonal*, such as the *monsoons* of the Indian Ocean. The Indian hot weather heats the whole surface of the country until, by the second or third week in June, it is hotter than the sea, causing the rarefied air to rise, and the cool moist winds from the Indian Ocean flow in from the S.W.—strong at first and gradually exhausting themselves. About October reverse currents in the mountains to the N. of India, and the cool dry N.E. monsoon results.

Other seasonal winds are :—the *khamsan*, a hot dry wind from the desert during the Egyptian spring; the *sirocco*, a hot moist southerly wind of the Mediterranean during spring and autumn; the *bora*, a cold dry N.E. wind of the Adriatic; the *mistral*, a cold dry N.W. wind of southern France; the *bise*, a cold N. wind of Switzerland, etc.

Land and sea breezes are common in many tropical places. The surface of the land is more heated during the day than the sea, and the air above it will rise, causing the sea breeze to flow in to take its place. At night radiation is more rapid from the surface of the earth, causing the "land breeze," or cooler air which takes the place of the warmer air over the ocean.

In taking observations, the *wind force* is roughly *described* by Admiral Beaufort's scale drawn up in 1806 and quoted in Scott's *Instructions in the Use of Meteorological Instruments*—

Beaufort Scale.	*Wind.*	*Velocity (in miles per hour).*
0	Calm	3
1	Light air	8
2	Light breeze	13
3	Gentle breeze	18
4	Moderate breeze	23
5	Fresh breeze	28
6	Strong breeze	34

Beaufort Scale	*Wind.*	*Velocity (in miles per hour).*
7	Moderate gale	40
8	Fresh gale	48
9	Strong gale	56
10	Whole gale	65
11	Storm	75
12	Hurricane	90

The *wind* is *measured* by an instrument called an **anemometer.**

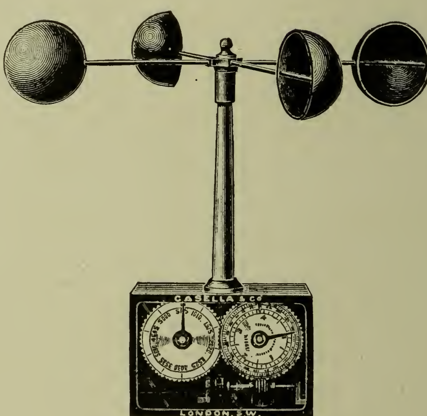

Fig. 22.

Some anemometers measure the *pressure.* Such are: Osler's, which consists of a plate supported by springs, which is driven back by the force of the wind; or Cator's, in which springs are replaced by levers. The only anemometer in practical use, however, is Robinson's, which measures *velocity* and not pressure. This instrument has four arms with a hollow cup at the end of each; it rotates horizontally, and the movements are communicated to a dial.

The velocity thus ascertained will give the pressure by Sir H. James' formula, $P = V^2 \times 0{\cdot}005$, where P is pressure in lbs. per sq. ft. and V is velocity in miles per hour.

In addition to the pressure and velocity, it will be necessary to record the *direction of the wind.*

A mean direction is taken to the nearest point of the compass.

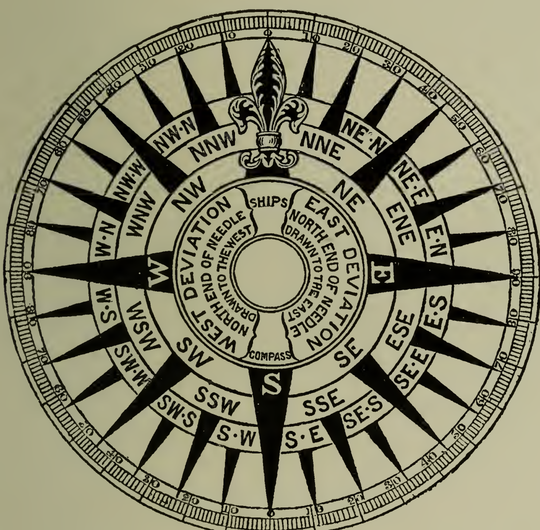

Fig. 23.

It is not necessary to read more closely than a 16-point compass. To each observation a numerical value of 4 is given.

Thus with a due S. wind, S. will have a full value of 4.

If the wind be S.E., the values will be 2 to S. and 2 to E.

If the wind be S.S.E., then S. would get three and E. one.

The numerical values of the four cardinal points are finally added up. The opposite directions are deducted from each other, and the net result calculated to the nearest point.

EXAMPLE.

Observations daily for a week—

	N.	S.	E.	W.
S.	—	—	—	—
S.S.E.	—	3	1	—
S.E.	—	—	—	—
E.S.E.	—	1	3	—
E.	—	—	4	—
E.N.E.	1	—	3	—
N.E.	—	—	—	—
N.N.E.	3	—	1	—
N.	—	—	—	—
N.N.W.	—	—	—	—
N.W.	2	—	—	2
W.N.W.	—	—	—	—
W.	—	—	—	—
W.S.W.	—	1	—	3
S.W.	—	—	—	—
S.S.W.	—	—	—	—
	6	5	12	5

Subtracting the opposite directions we get—

N 6	E 12
S 5	W 5
Net N. = 1	Net E. = 7

In this case the mean for the week will be N.Easterly, with a balance of 6 points in favour of E.

The quarter compass is 90°, and each of its 8 points = 11·25°.

Therefore the mean direction is E. by N.

Hygienic influence of wind.

Warm and moist winds do not favour body evaporation, and are therefore mild and relaxing.

Cold dry winds are bracing, but are unsuitable for cases of phthisis, rheumatism and congested liver.

Wind is a useful ventilating agent. Small-pox may be air-borne for a certain distance.

Cholera and enteric fever are spread to a small extent by wind-borne dust.

II. CLOUDS.

When air over water is saturated with vapour and becomes warmed, convection takes place and the air rises.

When high up, the pressure decreases, the air expands, its temperature falls, and it is unable to contain so much vapour. The surplus vapour condenses, and is held in suspension as **clouds**. These only differ from fogs and mists in being produced at a higher elevation.

By the *International Meteorological Conference*, at Munich in 1891, clouds are divided in 5 main groups according to their height or direction.

1. At 10,000 yards—

   * Cirrus; ** Cirro-stratus; Cirro-cumulus.

2. At 3,000 to 6,000 yards—

   * Cirro-cumulus; ** Cirro-stratus.

3. At 1,000 to 2,000 yards—

   * Strato-cumulus; ** Nimbus.

4. In ascending columns of air at 1,500 to 5,000 yards—

   * Cumulus; ** Cumulo-nimbus.

5. Fog bank sheets at 1,000 to 1,500 yards—
Stratus.
(* fine weather ; ** bad weather.)

The above will be seen to be compounds of 4 forms :—

Nimbus, or rain cloud, a dark, horizontal sheet, in association with cumulus.

Cumulus.—A mountain-like cloud with its vapour at greatest density, and existing as snow.

Cirrus, or wispy clouds, with vapour at small density, and probably composed of ice.

Stratus.—A stratified cloud often seen at sunset and due to a layer of atmosphere being cooled in bulk to near its dew-point.

The *physical effect* of clouds is to moderate the solar and terrestrial radiation, and therefore tend to equalise the temperature.

In *recording cloudiness* the amount is estimated from a clear sky (=0) to one entirely overcast (=10).

III. Rain.

Cloud, as we have seen, consists of condensed vapour held in suspension. When the temperature is still further lowered, the quantity of condensed vapour increases, and, being more than can be held in suspension, the minute particles unite and fall to the earth as drops of **rain.**

In many mountainous regions, such as parts of the Andes, Rockies, Himalayas, etc., there is excessive rainfall on one side and very little on the other. This is due to the air from the sea (which is saturated with moisture) meeting the mountain and being forced to rise ; it is then subjected to diminished pressure and lowered temperature, which will cause it to deposit its surplus moisture.

If the rain traverses a freezing stratum of air, **hail** will result.

If, however, a cloud is exposed to a freezing temperature before rain has formed, the water in suspension will freeze into small crystals, forming **snow.**

Winds are the chief immediate cause in producing rain, especially those blowing from low latitudes to high, and off the sea.

The greatest rainfalls known are on the Malabar Coast (263 in. per ann.); the Khasia hills, north of the Bay of Bengal (463 in. per ann.; with 805 in. in 1861).

The driest regions are the desert tract, comprising the Sahara, Arabia and Persia; and the Great Salt Lake region in North America.

Rainfall is *measured* by an instrument called the **rain-gauge.**

This instrument consists of a circular collecting funnel leading into a can. The area of the funnel should be 8 inches (Meteorological Office). The area of this circle (πr^2) will equal $3{\cdot}1416 \times 4^2 = 50$ square inches.

A fall of one inch of water will therefore give 50 cubic inches of water in the receiving can.

In cold climates the collecting funnel should be fitted with a vertical rim 6 inches deep to catch snow.

A foot of snow will yield about 1 inch of water.

Observations should be made every day at 9 *a.m.*, and the amount registered as having fallen on the *previous* day. The gauge should be firmly fixed in a well-exposed situation, at about 1 foot above the ground.

Rain has a certain *hygienic influence.*

It mechanically cleanses the air from dust and organisms, and also by moistening the ground prevents their rising again.

If excessive, the further factors of atmospheric humidity and damp soil must be considered.

IV. Humidity.

Water is constantly evaporating from the land and sea into the air.

The amount of moisture which the air can hold depends upon the temperature. For instance, a cubic foot of dry air can take up

at 0° C.	. . 0·138	grammes water
15·5° C.	. . 0·374	„ „
26·5° C.	. . 0·713	„ „
37° C.	. . 1·288	„ „

Air which contains the above amount of water is said to be *saturated.* In England, however, the relative humidity is rarely more than 75 per cent. at normal temperatures. This amount is of course enough to saturate the air if the temperature be lowered sufficiently.

Occasionally air may be *super-saturated,* and will then only deposit its moisture upon solid surfaces. The solid particles of dust and smoke will constitute the necessary nucleus; when these particles are large and numerous, and the quantity of condensed vapour is small, the familiar *town-fog* is the result.

During the night the earth parts with its heat by radiation. If there is much cloudiness the clouds receive the heat and radiate it back to earth, and thus no large amount of cooling takes place. If the night is clear there is no check to the terrestrial radiation, and rapid cooling takes place. This lowers the temperature of the air in the vicinity, and if this diminution brings it below the saturation temperature for the existing amount of vapour, the surplus will be deposited in the form of **dew.**

The dew-point is the temperature at which dew is first deposited from cooling air.

Good reflectors being bad radiators, such smooth objects as stone railings, etc., will radiate (and therefore cool) less than such objects as grass, etc. The latter will therefore have the greater deposit of dew.

The "hygrometric state" is the ratio of the actual pressure of water vapour the air contains, to the possible pressure if it were saturated.

In order to determine the humidity of the air we measure by means of an instrument called an *hygrometer.* These may be either *direct* or *indirect.*

Of direct hygrometers we have three forms, now rarely used—

Daniel's hygrometer.

This consists of two bulbs connected by a bent glass tube; one of the bulbs is partly filled with ether and contains a delicate thermometer. The internal space contains only ether vapour.

The second bulb is surrounded by a piece of muslin. Ether is dropped on the muslin, and the evaporation cools the contained ether vapour, causing some of it to condense.

More ether will in consequence evaporate from the other bulb.

The process continues until the temperature of the ether bulb falls below the existing dew-point, when moisture will be deposited on the bulb and the temperature is noted. The temperature of the bulb is allowed to rise again until the moisture on its surface disappears, when the temperature is again noted. The mean of these two readings will give the true dew-point.

Regnault's hygrometer.

This is a glass tube or vessel closed at one end and partly filled with ether. In the open end is placed a cork with a small tube passed through it until one end is below the surface of the ether. The lower part of the vessel is surrounded by a polished silver cap, and within is a delicate thermometer.

Above the level of the ether is an opening into the vessel through which the ether vapour is aspirated. Its place is taken by air passing through the cork tube and bubbling through the ether.

Regular evaporation thus takes place, and dew appears on the silver cap. The temperature is noted, as also the temperature at which the dew disappears; and the mean of these two readings will give the dew-point.

Dines' hygrometer.

In this instrument, ice-cold water is drawn through a pipe under a plate of black glass, the temperature of which is recorded by a thermometer, the bulb of which is underneath.

Of the *indirect hygrometers* there are two in use—

Saussure's hygrometer.

The principle of this is the lengthening of a piece of hair when moist, and contraction when dry.

The movements of the hair are mechanically communicated to a graduated dial.

It is very sensitive but requires frequent adjustment.

The **Psychrometer** (or wet and dry bulb) was invented by Hulton of Edinburgh, and August in Germany.

It consists of two thermometers on one frame.

The bulb of one is kept moist by a piece of muslin which dips in a water cup.

If no evaporation is taking place the temperature registered by the two thermometers will be equal—*i. e.* the air is saturated.

If the two thermometers show widely different readings, then much evaporation is of course taking place, *i.e.* the humidity is very low.

From the difference between the two readings can be

calculated both the dew-point, the tension of aqueous vapour (absolute humidity), and the relative humidity.

In thick fog or very calm weather, the wet bulb may actually read higher than the dry, in which case the latter should be taken as the temperature of saturation.

To find the dew-point by this instrument—

$$\triangle = D - \{(D - W) \times f\}$$

where D = dry bulb, W = wet bulb, and f is a certain factor (Glaisher's factor).

To find the relative humidity by this instrument—

$$\text{Rel. humid.} = \frac{f}{F}$$

where F is the vapour tension at the temperature, if saturated; and f the actual vapour tension at that temperature.

Tables have also been drawn up by Glaisher (1870) which show the relative humidity at a glance for all the different temperatures of the two bulbs.

The hygienic influence of humidity.

The body temperature is largely regulated by evaporation from the skin and lungs.

If the atmospheric relative humidity be high, skin evaporation will be retarded, and in hot countries this may give rise to thermotaxic disturbances such as febricula, etc.

In cold, moist climates, bronchitis and rheumatic conditions are prevalent.

It was previously thought that malaria, plague, etc., were influenced by climate, but we now know better.

Phthisis is rare in dry desert climates.

The atmospheric humidity has a valuable influence in mitigating the intensity of solar radiation.

V. Atmospheric Temperature.

The three *factors influencing the temperature* of any place are—

(*a*) Latitude.
(*b*) Altitude.
(*c*) Proximity to a large body of water.

(*a*) The chief source of heat is solar radiation. This will be greatest where most perpendicular; consequently between 23° N. and 23° S. (where the sun is vertically overhead twice a year) will be the hottest regions, *i.e.* the tropics.

For about 23° round both poles the sun never has a greater elevation than $23\frac{1}{2}°$.

(*b*) The actual *air* is heated more by dark-heat rays reflected from the earth than by direct solar radiation; so that the lower strata will be warmer, since the earth is warmer, and there is less radiation into free space than occurs at high elevations.

The decline of temperature is about 1° F. for each 300 feet of ascent, though this diminution is influenced by air currents, clouds, etc.

(*c*) Large bodies of water will absorb heat more slowly and give it out more slowly than the earth, since the specific heat of water is about five times that of the land. Proximity to such water will therefore tend to an equable temperature.

Distribution of temperature is shown by taking a map and connecting the places which have the same mean temperature by lines called **isothermals**.

The region of the *highest mean temperature* (isothermal = 90° F.) is a tract comprising the Sahara, Egypt, Nubia, Arabia, the Persian Gulf, Southern Persia, Afghanistan, Baluchistan and Sind.

The *maximum shade temperatures* recorded are—

130° F. at Murzuk (N. Africa),
127° F. at Cooper's Creek (S. Australia),
123° F. at Pachpadra (India),
122·2° F. at Jacobabad (India).

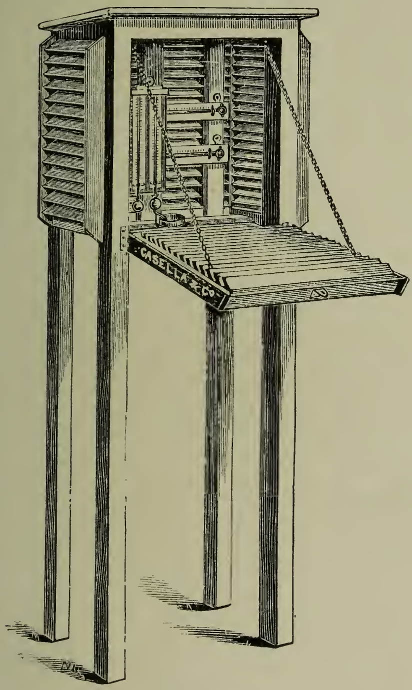

FIG. 24.

The *lowest mean monthly temperature* is −·56° F. (January) at Werchojansk in Siberia, which place also holds the record for the *minimum temperature* recorded (−·81° F.).

5

Thermometrical records deal with maximum and minimum shade temperatures and solar and terrestrial radiation temperatures.

Daily and monthly fluctuations, as also monthly and annual mean ranges, should be noted.

The shade temperature thermometers are best kept in some structure like a **Stevenson's Screen,** Fig. 24, p. 65, which may also conveniently hold a wet and dry bulb instrument.

If three observations are taken daily they should be at 6 a.m., 2 p.m., and 10 p.m.

If two readings—at 9 a.m. and 9 p.m.

If one reading—at 9 a.m.

The construction and graduation of thermometers has been dealt with in Chapter III.

Six's thermometer.

This instrument is still much used and was even more so before the introduction of the present maximum and minimum registering instruments.

There is a **U**-shaped tube, with the bend occupied by mercury. Above this the tube and bulb on one side (cold) is filled with alcohol; on the other side (hot) is some alcohol and air.

A small metal index in the alcohol rests on the surface of the mercury.

When heated, the cold bulb alcohol expands and drives down the mercury, causing it to rise and register in the "hot" bulb.

When cooled, the cold bulb spirit contracts and the air pressure in the hot bulb forces the mercury up the cold limb.

Philips's maximum thermometer.

This is a mercurial thermometer, the index of which is formed by a bead of the mercurial column separated from the rest by a bubble of air. The bead is pushed

on when the mercury expands, and remains behind when it contracts, thus registering the maximum reached. To set it, it has to be shaken.

Negretti's maximum thermometer.

This is also mercurial. The bore of the tube is attenuated close to the bulb.

Expansion will push the mercury forward, but the cohesion is not sufficient to draw it back on contraction, and the maximum is thus registered. It is set by being shaken like a clinical thermometer.

Rutherford's minimum thermometer.

This is an alcohol thermometer, and contraction will draw down a little metal index to register the minimum temperature. The spirit flows fast without moving the index when the spirit expands.

Casella's minimum thermometer.

This is a mercurial instrument, and very accurate, but difficult to manipulate.

There is a small pear-shaped chamber, of large bore, communicating with the small bore of the instrument just above the bulb.

The instrument is set by raising the bulb and allowing the mercury to leave the auxiliary chamber and almost fill the ordinary small bore of the instrument.

On contraction, the mercury retires along the indicating stem as usual; but on subsequent expansion the indicating column does not move, as the mercury finds an easier passage through the large bore of the auxiliary chamber.

Herschel's solar radiation thermometer.

This is a maximum mercurial thermometer with the bulb and 1 in. of adjoining stem coated with lampblack. The thermometer is enclosed in a bulb-ended tube, which is made into a vacuum and sealed up.

The thermometer is freely exposed to the sun in an open position on a horizontal stand about 4 ft. from the ground.

The "solar radiation" is expressed by deducting the shade maximum from the Herschel maximum.

Terrestrial radiation thermometer.

This instrument is to gauge the heat given out by the earth.

An alcohol minimum registering thermometer is enclosed in a glass case and fixed about 4 in. above a grass plot.

The minimum reading of the instrument deducted from the minimum shade temperature during the same period will give the amount of terrestrial radiation.

The *Effects of Temperature on Health* are very varied, and may be either direct or indirect.

(*a*) *Heat*—

1. The body heat is raised 0·05° F. for each 1° increase in air heat (Becher's law).
2. There is a spirometric chest increase of 7 or 8 % in the tropics.
3. The respiration rate is diminished.
4. The elimination of CO_2 is decreased.
5. Kidney secretion is reduced by 17 %.
6. The nervous system is ultimately depressed.
7. The establishment of menstruation is accelerated.
8. The growth of micro-organisms is much favoured.
9. The skin and liver are very active, and the latter organ is especially subject to congested states.
10. Intestinal disorders are frequent.
11. Excessive heat may upset the thermotaxic mechanism and result in diathermasia (heat-stroke).

12. Light rays may cause a severe cerebral shock (Phœbism), often called sunstroke.
13. Exposure to actinic sun rays will also cause a secondary melanosis (sunburn), and probably accounts for the hereditary primary melanosis in natives.
14. Moulds grow quickly, and skin diseases are common.

(*b*) *Cold*—

1. Chilblains and frostbite may occur.
2. Lung and rheumatic affections are favoured.
3. The kidneys have excessive work.
4. Micro-organisms are less active than in hot climates.
5. Specific fevers are less prevalent.

VI.—Atmospheric Pressure.

The construction and theory of the barometer has already been discussed in Chapter II.

For meteorological record a self-registering aneroid is sometimes used, in which the barometric movements are communicated by means of a lever (with a small pen) to record sheets on a revolving drum.

For scientific purposes, however, the best instrument is the

Standard barometer of Fortin.

In this instrument the cistern has a pliable base of leather which can be raised or lowered by a screw, *c*. Through the glass side of the cistern can be seen a dependent piece of ivory, which forms the zero of the scale, and is called the *fiducial point*.

Before taking a reading the level of the mercury must be set at exactly that point.

For correct reading to second and third places of decimals a secondary scale, known as a **Vernier**, is

attached to the barometer scale. In the vernier 25 divisions correspond to 24 on the barometer, and each small vernier division is 0·002 ($= \frac{1}{500}$ in.) smaller than the divisions on the fixed scale.

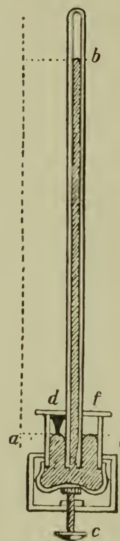

FIG. 25.—FORTIN'S BAROMETER.
(Reduced from Notter and Firth.)

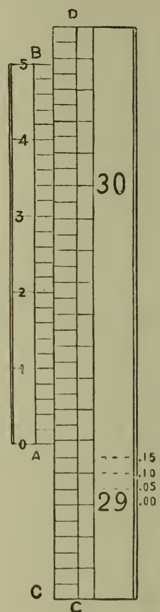

FIG. 26.—VERNIER.
(Reduced from Notter and Firth.

The lower edge of the vernier is adjusted to the top of the mercury meniscus. If the vernier zero is found to coincide exactly with a division on the barometer, then no further steps are taken.

If it does not, as in the annexed cut, then we write down the height of the next lowest mark on the barometer scale, *e.g.* in this instance—

29·15.

Now look up the vernier until a mark is found which coincides with one on the fixed scale.

In this case it is 3·4 divisions on the vernier. But each main division on the vernier = 0·01 in. Therefore the present vernier reading = $0·01 \times 3·4 = 0·034$.

This reading we add to the barometer reading above, *i.e.* $29·15 + 0·034 = 29·184$, or the true reading to three places.

The four corrections necessary in a barometer reading are for

(*a*) Capillarity,
(*b*) Temperature,
(*c*) Altitude,
(*d*) Index error.

The first and last are generally stated on the new certificate.

Corrections for temperature can be ascertained from a table, as also reductions for correction to sea level.

Measurement of heights by the barometer.

Scott's rule is to multiply by 9 the difference in barometrical readings (taken in hundredths of an inch) at the two required stations, and the result with decimals ignored, will give the altitude (in feet) of the one station above the other. With the barometer below 26, or the temperature above 70° F. the factor should be 10 instead of 9.

The results are correct to within 5 %.

Barometric readings form a good guide to **weather indications.**

When moisture evaporates into dry air, the volume of the latter increases—so that volume for volume the saturated air weighs less than the dry air.

Consequently when much moisture is present and rain is imminent the atmospheric pressure is diminished, and the barometer falls.

Synoptic charts.

By telegraphic reports simultaneous barometrical observations can be obtained from a wide area.

These are charted on a map, and spots of equal pressure are connected up by lines called **isobars.** The relative proximity of the isobars to each other is termed the "**barometric gradient,**" which is measured in so much of an inch in so many miles. Such gradients govern the velocity of the wind.

Isobars are classified by Abercrombie into 7 different types:—*i.e.*

Cyclone, *Secondary Cyclones*, *Anticyclones*, V-*shaped Depressions*, *High-pressure wedges*, *Straight isobars*, and *Cols.*

FIG. 27.

A = *Anticyclone.* *C* = *Cyclone.* *c* = *Col.* *I* = *Straight isobar.*
S = *Secondary cyclone.* *V* = *V-shaped depression.* *W* = *Wedge.*

Pressure over N. Atlantic and some of Europe and the United States, on February 27, 1865. (After Abercrombie.)

Cyclones are areas formed by concentric isobars, the lowest pressure being towards the centre. As a rule

they are oval in shape, and usually travel from West to East at about twenty miles per hour.

Their extent may vary from twenty to some hundreds of miles, but as a rule they do not cover anything like the area of an anticyclone, and if they should become extensive they frequently break up into several smaller centres of depression.

Certain small-area rotatory cyclones are common in the tropics under different names. They are of a circular type, of very steep barometric gradient, and the centre moves from 50 to 300 miles a day, in a somewhat parabolic course.

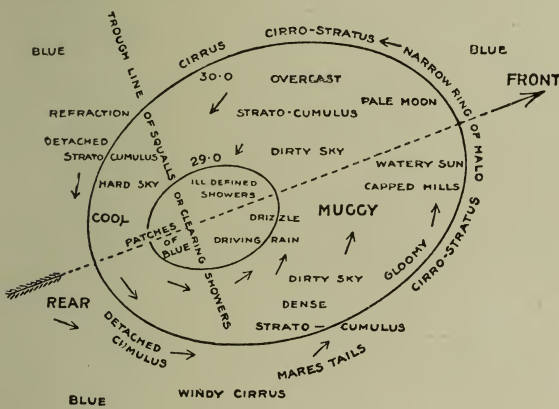

Fig. 28.—Diagram of Cyclone Weather.
(Reduced from Notter and Firth.)

As a rule they make up near the belt of equatorial calms. Those to the North revolve from Right to Left, those to the South of the equator from Left to Right. The worst are known as **Hurricanes**, which occur in the West Indies, and travel 300 miles a day, between July and October. Also in the South Pacific from December to March.

A type of rather less severity is the **Typhoon** of the China coast—July to November, which only travels about 200 miles a day.

Also **Rotatory Cyclones** of the South India ocean from December to April, and in the Bay of Bengal during April and May, and October to December, which travel from 50 to 150 miles a day.

Secondary Cyclones are looped isobars of incomplete circumference with low-pressure centre, and their bad weather is associated with a stationary barometer.

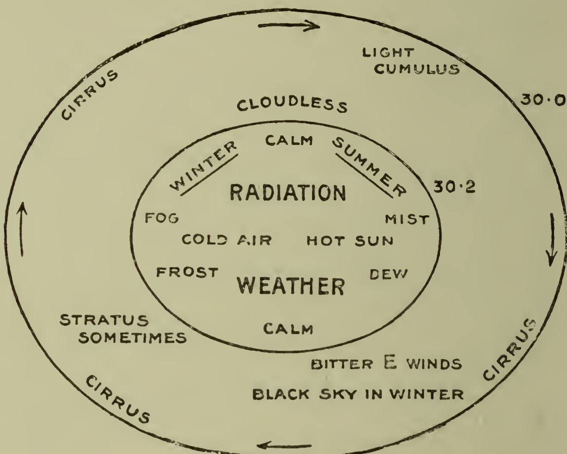

Fig. 29.—Diagram of Anticyclone Weather.
(Reduced from Notter and Firth.)

Anticyclones are oval isobar areas with a high-pressure centre. They are less intense than cyclones; are sluggish in their movements, and often extend over a very wide area. They are associated with sunshine, blue sky, free radiation, great daily range of temperature, and little wind.

V-Shaped depressions are a specialised form of

Cyclone forming an angular interval between adjoining anti-cyclones. They have a low-pressure centre and are always associated with squalls or thunderstorms.

Influence of atmospheric pressure on health.

The pressure variations, unless extreme, have only an indirect influence on health.

Under continued low-pressure the thoracic capacity is increased, and the vascular system stimulated; the general effect being good.

Reduced pressure at very high altitudes may cause epistaxis and other hæmorrhages; though in a balloon, with a very gradual ascent, as low a pressure as 8 inches of mercury has been endured without serious effects.

In diving-bells and other pneumatic chambers, a pressure of three or four atmospheres may be borne with impunity if the increase and especially the subsequent decrease of pressure be sufficiently gradual.

VII. Climate.

By "Climate" we mean the sum of the meteorological and telluric conditions.

Climates will fall under five geographical heads—Polar, temperate, sub-tropical, tropical, and equatorial.

1. *Polar.* Short summer, long winter, extensive snow. Very low temperatures.
2. *Temperate.*
   - (*a*) *Continental.* Normal pressure. Extremes of heat and cold. Moderate rainfall. Sky often clear. Winds variable.
   - (*b*) *Maritime.* Higher pressure. Equable temperature. Humidity great. Winds often regular.
   - (*c*) *Mountain.* Pressure low. Temperature low. Rain and Humidity great.
3. *Subtropical.* Has some of the characteristics of both temperate and tropical climates.

4. *Tropical.* Rainy seasons are usually periodical (twice yearly). There may be considerable variation of temperature, but with high mean.

   The skies are frequently clear. In deserts there is much radiation, with extremes of temperature and no rain.

5. *Equatorial.* This is the cloudy belt. Variations of pressure and temperature are only slight. The mean temperature is very high.

   Rain is considerable and frequent, with rainy seasons not well marked.

Acclimatisation is the process by which animals and plants become adapted to and thrive in a non-indigenous climate.

The debility of Europeans in the tropics is often due rather to indolence, sensual gratification and irregular living, than to the direct effect of the hot climate.

The *conditions favourable to acclimatisation* are :—

1. Slight alteration of latitude.
2. An ethnical disposition.
3. Sound physiological life.
4. Aptitude for cross-breeding.
5. Soil and locality.

The migration should be gradual and will take at least four or five generations.

Acclimatisation is complete when :—

1. The demographic expansion is preserved.
2. The normal longevity is preserved.
3. The normal aptitude for physical and mental work is preserved.

CHAPTER V

AIR

ATMOSPHERIC air consists chiefly of Nitrogen and Oxygen, with small amounts of other gases, and some suspended solids. That air is a **mechanical mixture** and not a chemical compound is shown by shaking up some air with water. In original air there are 4 vols. N to 1 vol. O, but in the gas expelled by boiling the shaken water, there are less than 2 vols. N to 1 vol. O.

The **average composition of air** is :—

1. *Nitrogen.* 78 % by volume.
2. *Oxygen.* 20·96 % by volume.
3. *Argon.* 1 % by volume.
4. *Carbonic acid.* 0·04 % by volume.
5. *Ammonia.* Traces.
6. *Water vapour.* Varies (with temperature) from 1 to 10 or more grains per cub. ft.
7. *Ozone.* Variable, greatest near sea.
8. *Hydrogen.* Exists in free state in about 2 vols. per 10,000.
9. *Organic matter.* In vapour or in suspension—traces.

The above constituents of air will vary according to the locality. In *towns* there will be a slight increase in CO_2 and organic matter, a decrease in O, and Carbon and Sulphur will be in excess.

Pure *sea or mountain air* may contain as much O as

20·999 % by volume, with a minimum quantity of CO_2 and organic matter.

Near *marshes, sewers or gas works* H_2S will be found as a constituent.

The composition of the air is kept constant by the process of diffusion, which distributes the chief atmospheric impurity (CO_2) in situations where the sunlight and plant chlorophyll can split it up into C for the use of the plant and O for the use of man.

In addition to diffusion, wind and rain are also at work as purifying agents.

I. Atmospheric Impurities.

(1) **Carbon Dioxide** (CO_2).

This gas occurs as a normal constituent from small amounts up to a volume of 0·04. Amounts above this are reckoned as atmospheric impurity and are highly prejudicial to health.

From the total percentage, the normal 0·04 must be deducted, and the excess reckoned :—

In confined spaces such excess may be classified :—

0·04 % = Rather close atmosphere.
0·06 % = Close atmosphere.
0·08 % = Very close atmosphere.

The gas is given off by *animal respiration*, mostly from the lungs but partly from the skin.

An adult at rest exhales an *average of* 0·6 *c. ft. CO_2 per hour.* The amount is less for women, children, and the aged, and is increased by active exercise.

The following table (from Notter & Firth) will give some idea of CO_2 impurity :—

Gosport Barracks (de Chaumont)	0·06 %
Strand Theatre, London (Smith)	0·101 %
Chatham Prison (de Chaumont)	0·169 %
Chancery Court, London (Smith)	0·193 %
Assize Court, Manchester (Smith)	0·196 %
Public Library (Weaver)	0·206 %
National Schoolroom, Leicester (Weaver)	0·241 %
Mine in Cornwall (Smith)	0·785 %

The gas is also given off by *putrefactive processes*, by some *soils*, and by *combustion processes*.

Lighting and *heating* account for much air impurity, as well as exhaustion of Oxygen.

One lb. coal consumes about 240 c. ft. of air, and its products of combustion are :—

1. Water	16 % by weight
2. CO_2	300 % by weight
3. C	1 % by weight
4. CO	traces.
5. SO_2	traces.

In *lighting* processes 1 c. ft. of coal gas combines with about 8 c. ft. of air, and raises the temperature of 31,300 c. ft. of 1° F. The best combustion is assured by the use of a suitable burner—such as the Welsbach, Siemens, or Argand.

Ordinary coal-gas is from 13 to 30 candle power, and produces in combustion about 7% CO_2.

The *composition of coal gas* is as follows :—

Illuminants		
	C_2H_2 (acetylene)	2·5 %
	C_2H_4 (olefiant gas)	3·5 %
Diluents		
	H (Hydrogen)	45 %
	CH_4 (Marsh Gas)	38 %
	CO (Carbon Monoxide)	4·5 %
Impurities		
	CO_2 (Carbonic Acid)	3 %
	N (Nitrogen)	2 %
	H_2S (Sulphuretted Hydrogen)	0·5 %
	SO_2 (Sulphur Dioxide)	0·5 %
	CS_2 (Carbon Disulphide)	traces

Other combustion processes, such as wood and oil, use rather less air.

Tobacco smoke contains excess of Ammonia, CO_2 and butyric acid vapour.

(2) **Ammonia** (NH_3).

This impurity is derived from decomposing nitrogenous matter, and is found in greatest quantities in latrines, smoking-rooms, or rooms containing many

people, when the amount may reach 0·5 mgr. per cub. metre.

In the outside air it is rarely more than 3 parts per 10 million.

It is readily soluble, and thus is quickly removed by rain, forming a valuable food for plants.

(3) **Carbon Monoxide** (CO).

This is a product of imperfect combustion, and is produced in considerable quantities by some gas or other stoves. It is highly dangerous, and a percentage of 0·005 will cause poisoning symptoms such as dizziness, headache and suffocation. Its action is to displace the oxygen in the blood, forming a poisonous compound with the hæmoglobin.

(4) **Sulphur** (as H_2SO_3, H_2SO_4, SO_2 and H_2S).

This results from the combustion of coal and gas, from chemical factories, sewers or marshes.

It is a common constituent of the air of towns and is very prejudicial to vegetable life, though not in sufficient quantities as a rule to seriously affect human beings.

(5) **Suspended Matters.**

These are of very varied type and may comprise *road dust, soil dust, seeds and vegetable débris, pollen, spores, micro-organisms, living and dead animal matter, dried excreta, tarry matter*, and other forms of carbon, *epithelial cells, clothing fibres, sodium chloride, silica, calcium phosphate and carbonate, sand, volcanic mud and dust, dust from unhealthy occupations*, such as wool and silk carding; shoddy grinding; coal, iron, and lead mining; pigment making; drug mixing; emery working; etc., etc.

The diseases caused by this means may comprise :—*specific fevers, phthisis, fibroid phthisis, hay-fever, metallic poisoning*, and various chronic diseases.

These will, of course, depend on the nature and amount of the inhalation.

II. Ventilation.

By this we understand, the dilution or removal of the products of respiration and combustion from human and other habitations.

Cubic Air Space Required.

Under ordinary circumstances air at 60° F. moving at more than 3 ft. per second is felt as a *draught*, and the air of an ordinary-sized room cannot be changed more than 3 times an hour without discomfort to the highly strung individual.

At higher temperatures greater air currents can be maintained without inconvenience.

We must however allow for a change of air three times an hour, and *the cubic space per head should be so allotted as to give $\frac{1}{3}$ the amount of air required by the individual each hour.*

It will be remembered that inspired air contains 0·04 % of CO_2, and expired air 4·04 %.

Therefore 4 % of CO_2 is given off at each expiration.

And, since the respiratory capacity is 30·5 cub. in., the CO_2 expired will equal $\frac{4 \times 30 \cdot 5}{100} = 1 \cdot 22$ cub. in.

The respirations being about 17 a minute, it follows that 0·72 cub. ft. of CO_2 will be expired per hour.

Allowing for a diminished amount on the part of women and children 0·6 cub. ft. is generally allowed as the adult exhalation of CO_2 per hour.

Now, 1000 cub. ft. of ordinary air contain 0·4 cub. ft. of CO_2; and one adult will increase this amount by 0·2 cub. ft. in one hour, making the total of 0·6 cub. ft. Such an amount is not markedly unhealthy, and is indistinguishable by the sense of smell, and this balance

of 0·2 *cub. ft. of* CO_2 *to* 1000 *cub. ft. of air is known as the* standard permissible impurity.

1·5 to 2 % of CO_2 will cause headache, giddiness, and other bad symptoms.

Anything from 5 to 10 % may be fatal.

With regard to a taper burning in an atmosphere containing CO_2, it should be remembered that it will burn readily up to 8 %, at 10 % less so, at 12 % will be extinguished unless very vigorous, and at 16 % will be instantly extinguished.

The whole scheme of ventilation is therefore directed to keeping the CO_2 down as nearly as possible to 0·6 parts per 1000, *i.e.* 0·2 part per 1000 in excess of the normal atmospheric CO_2.

From the above data it is possible to calculate the amount of fresh air necessary for each adult; for :—the (excess of CO_2 per cub. ft.) is to (one cub. ft. of air) as (the amount of CO_2 exhaled) is to (the total delivery of air). *i.e.* r : 1 : : E : D

$$\therefore \quad D = \frac{E}{r}$$

Now we know that

$$E = 0{\cdot}6 \text{ and } r = 0{\cdot}2 \text{ per } 1000 = 0{\cdot}0002 \text{ per cub. ft.}$$

$$\therefore D = \frac{0{\cdot}6}{0{\cdot}0002} = 3000 \text{ cub. ft.}$$

And by our rule we must provide $\frac{1}{3}$ of this amount (*i.e.* 1000 cub. ft.) to each individual per hour.

To secure this is, of course, easy in the tropics, where doors and windows need seldom be closed. But in the towns of colder regions the matter is otherwise. The poorer classes rarely secure 200 cub. ft. per head in the slums. In elementary schools the minimum allowance is from 100 to 120 cub. ft. per head. In workshops and factories 250 cub. ft. are required for each person

and 400 cub. ft. during overtime. In barracks 600 cub. ft. is the minimum.

Floor-space is necessary as well as a proportion of cubic contents, otherwise vitiated air in rising would interfere with the health of the superimposed individual. The fo'castle quarters of the crew on steamers are very badly off in this respect. In hospitals the cubic space per bed should be at least 1500 cub. ft., and the floor space 100 square feet.

The advantage of height in increasing the cubic contents of a room will be done away with if there is no upper ventilation, since the upper impure layers are with difficulty dislodged by any natural ventilation.

The *quality* of incoming air is of as much importance as the quantity, and in large towns it may be necessary to wash or filter it.

Natural Ventilation.

Such ventilation is carried on by (1) *gaseous diffusion*, (2) *convection currents* and (3) *wind*.

Diffusion proceeds rapidly through sandstone, bricks and mortar, especially if there is a considerable difference between the outside and inside temperatures; but the ventilation from this source is inconsiderable if other means of ventilation are present.

Vitiated air, being the product of high temperature combustion or warm expired air, is lighter than cold fresh air, and will consequently rise by convection currents. This physical fact is of much use in practical ventilating.

The action of wind is either by *perflation* or *aspiration*. By perflation is meant free ingress through doors and windows, and is a most efficient means of ventilation, unless the air be derived from mephitic city slums.

Aspiration is the upward suction caused by a wind blowing over a chimney—unless, however, the current

is directly at right angles to the axis of the chimney an impending down draught may be caused.

The following are the chief mechanical appliances adopted to make use of the three methods of natural ventilation:—

(1) **Window Ventilation of Hinckes Bird.**

A piece of scantling is placed beneath the lower window-sash, which is then lowered on to it. A permanent ventilating slit is thus formed between the upper and lower sashes.

(2) **Louvre Ventilator.**

One pane (best to have the lower pane of the upper sash) is replaced by glass slats, like a Venetian blind, slanting upwards and inwards.

(3) **Cooper's Ventilator.**

This is a movable disc of glass with 5 holes which is attached to one of the window-panes in which are a similar number of holes. By rotating the disc the inner and outer holes can be superimposed or not, just as required.

(4) **Ellison's Bricks.**

These are air-bricks which are inserted in an outside wall. The depth of a brick is about $4\frac{1}{2}$ in. It is perforated with conical openings having the apex outwards. The external opening has a diameter of $\frac{1}{5}$ in., and the internal $1\frac{1}{4}$ ins.

The wind enters through the openings and diffuses gradually, owing to the lessened velocity occasioned by the conical enlargement.

(5) **Jenning's Bricks.**

These are similar to those of Ellison, except that the perforations point upwards.

(6) **Sheringham Valve.**

This is an iron frame inserted in the place of a brick, and is closed by a plate hinged at the bottom, so that the latter can fall forward at will and thus provide an air inlet directed upwards.

They are usually placed near the top of a room, and may act as an outlet as well as an inlet.

(7) **Steven's Drawer Ventilator.**

This is like a metal drawer, having a knob to pull it out with, but has no back.

When it is drawn out the wind will enter from the outside and be directed upwards.

(8) **MacKinnell's Ventilator.**

This consists of two concentric tubes connecting the ceiling of a room with the outside air.

The inner tube (outlet) is longer than the other, and is protected by a cowl.

The outer tube (inlet) has a free area larger than that of the inner tube, and, within the room, the incoming air is directed along the ceiling by a flange attached to the inner tube.

(9) **Tobin's Tube.**

This is one of the most efficient ventilators. At about the floor level there is an entrance from the outside air which is larger than the bore of the remaining tube. An external hinged plate will regulate the amount of air coming in. The air, after entering, is directed by a flange over the surface of a small water-pool to cleanse it, and then goes vertically upwards through a tube of 6 to 12 inches diameter, fixed against the wall of the room.

This tube terminates at about 4 to 6 feet above the floor in a funnel-shaped and screened exit.

(10) **Boyle's Ventilator.**

This is an opening made near the ceiling into a chimney.

The opening is closed by small hinged flaps of mica which open towards the chimney-shaft, and thus allow the air from the room to enter the chimney, but prevent smoke or chimney-draught to enter the room.

We now come to—

Artificial Ventilation.

This is carried out either by *extraction* or *propulsion.* Extraction is secured either by the use of heat or by fans. Examples of heat are—**Sunlights,** *i.e.* an arrangement of gas-jets round the foot of an outlet-shaft; **Fire-stoves and flues,** the up-draught of which is used to withdraw air through perforated openings near the ceiling. This is the means used to ventilate the House of Commons, the removal of the upper foul air being concurrently supplemented by the entry of filtered and warmed fresh air under the floor and benches.

In an ordinary chimney the average upward velocity is 3 *to* 6 *feet per second, giving a discharge of* 10,000 *to* 20,000 *cubic feet per hour.*

Steam Jets may also be used in conjunction with a flue or chimney, instead of a fire, and will induce a strong upward current.

Other extraction and propulsion systems will comprise the use of fans.

In *mines* the best type is **Guibal's fan**—a centrifugal fan having the air entry round the axle. It revolves in a circular chamber, and the air is driven centrifugally by the vanes into a discharge pipe.

For rooms the best type is **Blackman's fan,** which is a revolving wheel with metal vanes. It may be driven by any motive power, and can be used to extract or propel according to the way in which it is turned.

III. Practical Ventilation Survey.

The following points will have to be noted:—

1. The smell, which should be noted when first entering the room.

2. The temperature by wet- and dry-bulb thermometers, which should be hung up on entering the room.

3. The aspect of the room with regard to prevailing winds, etc.

4. The situation and nearness or otherwise of overshadowing buildings, factories, etc.

5. The number of people by whom the room is to be used; whether temporarily or permanently; whether by day or night.

6. The number, nature, and size of all openings into the room.

7. The cubical contents, including recesses containing air and deducting for furniture and persons of inmates.

(Note.—Bedding may be taken as 10 cubic feet per person. The weight of a man in stones, divided by 4, will give his approximate cubic contents in feet.)

8. The direction of the air currents as ascertained by smouldering velvet.

9. Measurement of the delivery of air, or else of the discharge of air, either by air meter or Montgolfier's formula.

10. A determination of the CO_2.

11. Occasionally a bacteriological examination may be necessary.

(Note.—The excess of organisms over those of the outside air should not exceed 20 per litre; and the ratio of bacteria to moulds should not be more than 30 to 1.)

Measurement of cubic space.

In measuring curved or irregular spaces the follow-

ing superficial or cubic measurements should be remembered—

Area of a circle = πr^2 = 3·1416 × sq. of radius.
Circumference of circle = $\pi 2r$ = 3·1416 × diameter.
Segment of circle = $\frac{\text{height cubed}}{\text{chord} \times 2}$ + ($\frac{2}{3}$ × chord × height).
Area of triangle = base × $\frac{1}{2}$ height.
Solid cube = length into breadth into height.
Solid triangle = area × height.
Sphere = $\frac{4\pi r^3}{3}$.
Cone = area of base × $\frac{1}{3}$ height.
Dome = area of base × $\frac{2}{3}$ height.
Cylinder = area of base × height.

Measurement of air delivery.

This may be done by—

Cassella's air meter or small fan with dial attachment (like a gas meter) showing feet, 10 feet, 100 feet, and 1000 feet.

The number of lineal feet passing through an opening during 5 mins. is recorded.

This figure × 12 (will give inches per 5 mins.) × 12 (will give inches per hour) × square inches of outlet hole, and the whole total ÷ 1720 will give cubic feet per hour.

Examination of air for CO_2.

(*a*) **Pettenkofer's method.**

Apparatus required—

1. Glass-stoppered bottles of 4½ litres capacity, filled with pure water and protected with a rubber cap.

(Note.—This is the only apparatus necessary for examination on the spot. The rest is done in a laboratory.)

2. Clear lime water.

3. Standard solution of oxalic acid * (1 c.c. $= 0{\cdot}5$ c.c. CO_2).
4. A 50 c.c. burette.
5. A 60 c.c. and a 25 c.c. pipette.
6. A solution of phenolphthalein or methyl orange.
7. Two beakers and stirring rods.

The process—

1. Empty the jar of water in the room to be tested. It will then be filled with the air to be tested.

(NOTE.—The temperature of the room should be recorded.)

2. Add 60 c.c. of the clear lime water, replace the stopper, shake well and allow to stand for 8 hours.
3. Take 25 c.c. of the standard lime water, add some methyl orange or phenolphthalein, and titrate with the standard oxalic acid, noting the result.
4. After the 8 hours' standing of the sample, take 25 c.c. and titrate.
5. The difference between this latter titration and the titration of the standard lime water represents the c.c. of CO_2 in (4500 c.c. − 60 c.c. =) 4440 c.c. of the air to be tested.
6. A correction for temperature will be necessary:—

Add 0·2 % to the result for each 1° F. above 32°, and subtract for each degree under.

Explanation—

The lime water absorbs the CO_2, and calcium carbonate is formed. $Ca(OH)_2 + CO_2 = CaCO_3 + H_2O$.

The alkalising power of the $Ca(OH)_2$ is diminished according to the amount of $CaCO_3$ formed, since the $CaCO_3$ is a neutral salt. The alkalising power of the standard lime water is therefore first found, and then its alkalising power after some of the $Ca(OH)_2$ has been converted by the CO_2 into $CaCO_3$.

* Dissolve 28·19 grams oxalic acid in 1 litre of distilled water. For use take 10 c.c. and dilute with 90 c.c. water; this will give 1 c.c. $= 0{\cdot}5$ c.c. CO_2.

The difference will, of course, indicate how much CO_2 has been at work.

(*b*) **Lunge and Zeckendorf's method.**

Apparatus required—

1. A 70 c.c. wash bottle.
2. A 70 c.c. india-rubber ball pump.
3. A 2 c.c. pipette.
4. A 10 c.c. pipette.

The process—

1. 10 c.c. of a $\frac{N}{500}$ Na_2CO_3 solution * (containing 1 gram of phenolphthalein per litre) are put into the sample bottle.

2. The ball pump is squeezed empty and then released in the air to be tested.

3. This contained air is bubbled through the solution in the flask and the bottle shaken. The process is repeated until the phenolphthalein is decolorised.

4. The number of ballfuls used will indicate the CO_2 by reference to the following table—

Number.		% CO_2.	Number.		% CO_2.
2	=	3·0	14	=	0·77
3	=	2·5	15	=	0·74
4	=	2·1	16	=	0·71
5	=	1·8	17	=	0·69
6	=	1·55	18	=	0·66
7	=	1·35	19	=	0·64
8	=	1·15	20	=	0·62
9	=	1·0	22	=	0·58
10	=	0·9	24	=	0·54
11	=	0·87	26	=	0·51
12	=	0·83	28	=	0·49
13	=	0·8	30	=	0·48

* A normal solution is made by dissolving 53 grams of Na_2CO_3 in a litre of distilled water. 1 c.c. of this standard diluted with 499 c.c. of water will give a $\frac{N}{500}$ solution.

Detection of other gaseous impurities.

In the neighbourhood of chemical works various injurious gases may be present, though scarcely in sufficient amount to prove prejudicial to human beings in the vicinity.

In actual sanitary practice their detection is practically never required, but for D.P.H. examination purposes several jars of gases are often presented for qualitative analysis.

These are generally one or more of the following—

Air, CO, CO_2, NH_3, $(NH_4)_2S$, H_2S, CS_2, Cl, HCl, HNO_3, NO, N_2O_3, NO_2, SO_2 or coal gas.

Directions for testing—

1. Note colour.

Cl = greenish yellow. N_2O_3 or NO_2 = brown red.

2. Note smell on quickly and slightly raising stopper.

NH_3, H_2S, CS_2, SO_2, or coal gas, can all be detected by characteristic smells.

3. The escape of red fumes will indicate (if the gas was colourless in the bottle) the presence of NO.

4. The following test papers should be *moistened* and attached all round a piece of cork by means of pins. They can then be lowered into the gas by a piece of string, and the stopper replaced, *e.g.* red litmus, blue litmus, turmeric, lead acetate, starch and potassium iodide, and potassium bichromate.

Then—

(1) HCl and HNO_3 turn blue litmus red.

Dissolve in water. Add $AgNO_3$.

White precipitate = HCl. No precipitate = HNO_3.

(2) The red litmus turns blue and the yellow turmeric turns brown = NH_3.

(3) The papers are bleached = Cl.

(4) The lead acetate turns black = H_2S or $(NH_4)_2S$. With the latter the red litmus turns blue in addition.

(5) The bichromate paper turns green = SO_2.

(6) The starch and KI paper turn blue = N_2O_3 or Cl (also O_3 or H_2O_2 or other such oxidising agents).

(7) If the contents are odourless and do not react with above tests it may be air, CO or CO_2.

Add some lime water and shake. If milky = CO_2. If unchanged insert lighted taper. It goes out = CO. It burns = air.

CHAPTER VI

WATER

WATER is one of the most essential of the vital requisites.

Its uses comprise drinking, cooking, washing, sewage removal, manufacturing purposes, fire extinguishing; besides its meteorological necessity, and the requirements of vegetable and lower animal life.

I. COMPOSITION AND PHYSICAL AND CHEMICAL PROPERTIES.

Water is a chemical compound of two vols. of H to one vol. of O ($=H_2O$).

It is (when pure) clear, transparent, and devoid of taste, smell, or colour; though, when viewed in bulk it is bluish.

It freezes at 0° C.; its maximum density is 4° C.; it boils at 100° C. (N. P.); its specific gravity is 1.

Many solids and gases can pass into the liquid state when introduced into water; *i. e.* they are **soluble** in water. The solubility of gases depends—

(*a*) Upon the nature of the gas, *e.g.* 1000 vols. of NH_3 will dissolve in 1 vol. water, but only 0·02 vol. H in 1 vol. water.

(*b*) Upon the pressure.

The greater the pressure, the greater the amount of gas dissolved.

(*c*) Upon the temperature.

The lower the temperature, the more gas dissolved.

Some liquids such as alcohol or glycerine are **miscible** with water in all proportions; others, such as chloroform, only in small proportions.

Some chemical compounds will form a loose union with water, known as "**water of crystallisation**," *e. g.* $K_2CO_3,10H_2O$, or $CuSO_4,5H_2O$, etc.

Some chemicals part with their water of crystallisation on simple exposure to the air = **efflorescence.**

Other chemicals can absorb water from the air = **deliquescence.**

One litre of pure water weighs 1 kilogram; 1 cub. ft. weighs 1000 oz. av.; 1 gal. weighs 10 lb. av.

In addition to the pure water which is derived from many sources (discussed later) water is also found in nature in conjunction with many chemical salts.

Sea water

has 3·5 % of dissolved solids. These dissolved solids are as follows—

$NaCl$	77·75 %
$MgCl_2$	10·88 %
$MgSO_4$	4·74 %
$CaSO_4$	3·60 %
K_2SO_4	2·46 %
$MgBr_2$	0·22 %
$CaCO_3$	0·35 %

Aperient Saline waters.

$MgSO_4$ — *Leamington, Epsom.*

$\left.\begin{array}{l} Na_2SO_4 \\ NaCl \end{array}\right\}$ *Scarborough, Cheltenham.*

Alkaline waters.

Na_2CO_3 $NaHCO_3$ Free CO_2	*Vichy, Carlsbad, Ems, Seltzer, Apollinaris, Malvern, Marienbad.*

Calcareous waters.

$CaHCO_3$ $CaSO_4$	*Bath, Matlock, Bristol, Contrexéville.*

Chalybeate waters.

$FeCO_3$ Free CO_2	*Spa, Cheltenham, Tunbridge, Schwalbach, St. Moritz.*

Sulphuretted waters.

Free H_2S — *Harrogate, Aix-la-Chapelle, Aix-les-Bains, Luchon, Cauterets.*

II. Sources of Water.

Terrestrial water remains more or less in equilibrium. Evaporation is constantly proceeding from seas, lakes, rivers, soil and vegetation, and the water vapour returns to it again in the form of rain, snow, hail, mist and dew.

The following are the chief sources from which we derive our water supply—

(*a*) **Rain water.**

Owing to its lack of salts this is very soft. It is wholesome as collected in the country, but in towns the water may have absorbed much NH_3, HNO_3, H_2SO_4, H_2S, tar, soot, and organic matter.

Pure rain-water is, however, well aerated, and contains about 25 c.c. of gas per litre ($O = 8$ c.c., $N = 16{\cdot}5$ c.c., $CO_2 = 05$ c.c.).

(*b*) **Surface water.**

That is, rain water which has washed the soil, but not penetrated it.

It differs from rain-water in having more dissolved salts.

In regions remote from man, with a minimum of vegetation, surface water may be very pure.

Near human habitations it may be polluted by excreta, artificial manure, trade effluents, or vegetable decomposition.

(*c*) **Spring water.**

This is rain-water which has percolated the soil and absorbed CO_2 from the ground air. It is, in consequence, able to take up the carbonates of calcium, potassium, sodium, and magnesium.

In appearance it is clear, cool and sparkling, and has an agreeable taste. The location depends on the geological formation.

Dip springs.

These are common where sand and gravel lie above clay. The water is held up by the impermeable stratum at shallow levels, and issues as a spring where the permeable strata are cut, *e. g.* as by a river valley. They are intermittent; and being shallow, are liable to contamination.

Fissure springs

occur at great depths in granite formations, and are forced up by the pressure through natural fissures.

Junction springs.

These are generally deep springs met with at geological "faults." The water on meeting impermeable strata will leave its own stratum and rise to the surface.

(*d*) **Wells.**

The ground water is artificially tapped.

Shallow wells.

These are sunk in permeable strata, not as a rule more than 50 ft. deep.

The water may be palatable, but is highly liable to be contaminated by surface and subsoil water. The sides of the well should be of brickwork and cement for at least 20 ft. from the surface.

Deep wells.

These tap deep collections of water below an impermeable stratum. They are 100 or more feet in depth. The well should be bricked and cemented to a considerable depth.

The water is usually pure, well aerated, but often contains mineral salts, and is therefore a hard water.

Artesian wells.

These are borings to a great depth—of 1500 to 2000 ft. and more. They were first employed, in 1835, at Grenelle, in Artois (France) where a head of 60 ft. was obtained by a boring of 1800 ft.

They tap water-bearing strata below an impermeable stratum; and, by a basin-shaped arrangement of the latter, secure water from a great distance, since the outcrops which form the collecting surface are often very many miles from, and at a considerably higher level than, the well.

The water is pure, though hard and often not well aerated.

(*e*) **River water.**

From ancient times advantage has been taken of rivers to build towns on their banks; thereby a waterway for traffic, a water supply, and an outlet for sewage

are immediately secured. The danger in rivers comes from the discharge into them of trade and sewage effluents.

A river, in course of time, tends naturally to purify itself. This is brought about (1) by the gradual deposit of solids on the river bed, (2) by oxidation due to the action of air at the surface of water in continual motion, (3) by the action of living animal and vegetable matter in the water, and (4) by the action of light.

The Rivers Pollution Commissioners laid down, however, that "there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation."

The impurity from bacterial contamination can be obviated by the use of sand filtration. A good sand filter (as Koch has shown) does not act properly until a slimy layer has formed on the surface. When this layer gets too thick and impedes filtration, it has to be removed and fresh sand replaced—but the subsequent water supply should be discarded until a new layer of slime has formed.

(*f*) Lake water.

This is much the same as upland surface water. Its expanse favours subsidence of suspended solids. Its purity will largely depend on the streams or rivers which feed and drain it, and on the presence or absence of towns and villages on its shores.

(The lake of Geneva shows total solids 12·8 parts per 100,000; 0·52 being Cl; 1·15 magnesia; 3·8 SO_3, and 4·23 lime.)

(*g*) Sea water.

Use can be made of sea water if efficiently condensed. The condensed water will need aeration, and should show only the barest trace of chlorine by chemical tests.

(At the St. John's Island Quarantine Station, at Singapore, a large condensing plant with two boilers is in working order. The condensed sea water is pumped up to a reservoir (on a hill) into which it flows by delivery from a long perforated pipe, and the water is aerated by dropping from some height on to the edge of a triangular board.)

III. Collection and Storage and Distribution of Water.

Rain water is seldom utilised in England except for external and garden uses. It is very apt to be contaminated in towns; and, if it has absorbed any SO_3, it will act freely on metals. It should therefore be stored in earthenware or slate or cement-lined tanks. *Lakes* may serve as impounding reservoirs, *e.g.* Thirlmere for Liverpool; or *Rivers, e.g.* the Thames for some of the London water supply.

In most cases a preliminary filtration through sand-filter beds will be necessary.

It is then necessary to send the water to a **high-level reservoir** in order to give it sufficient "head" for distribution by gravitation. The *size of the reservoir* is important, and is calculated as follows:—

$$\underset{\text{(in c. ft.)}}{\text{Size}} = \frac{\text{Population} \times \begin{smallmatrix}\text{Amt. water}\\ \text{required per}\\ \text{head in gals.}\end{smallmatrix} \times 1000}{6{\cdot}23 \times \sqrt{\text{mean annual rainfall}}}$$

(Note.—$\dfrac{1000}{\sqrt{\text{rainfall}}}$ is *Hawksley's Formula* for calculating the number of days' supply to be stored.)

The *condition of the reservoir* should be attended to. Protococcus and chara do no damage to water, but duckweed and some other aquatic plants are injurious. They should be covered and ventilated. The water leaves the reservoir by mains which pass beneath the streets. These consist of large cast-iron pipes, which are galvanised or protected with a vitreous glaze

(De Lavenant), or exposed to superheated steam while hot (Barff), or coated with bituminous varnish (Angus Smith). The *size of the mains* is important. The greatest hourly demand is about double the average hourly demand.

The discharge through the mains can be thus calculated :—

$$\underset{\text{(in c. ft. per min.)}}{\text{Discharge}} = 4{\cdot}72 \frac{\sqrt{\begin{pmatrix}\text{Head of water}\\ \text{in feet}\end{pmatrix} \times \begin{pmatrix}\text{Diam. of pipe}\\ \text{in inches}\end{pmatrix}^5}}{\sqrt{\begin{matrix}\text{Length of pipe}\\ \text{in feet}\end{matrix}}}$$

The mains should be laid as far as possible away from sewers and gas mains. They should have "scouring valves" at all "dead ends."

From the street mains, the water reaches the houses by **service pipes.** These are generally made of galvanised iron, and should be protected on their inner surface in the same way as the mains.

Service Distribution.

There are two systems of distribution generally in use. These are the **Intermittent Water Supply** and the **Constant Water Supply.**

In the former case, the mains are not kept constantly full, but the water is only turned on at certain times.

This intermittent system has been defended on the score of economy of water; but it has no other advantage, and has been abandoned in most places. It will of course necessitate storage room in each house for a two or three days' supply.

The *disadvantages of the Intermittent System* are :—

1. Emptying mains is liable to suck in impurities.
2. Intermittent charging of mains will favour corrosion.
3. House-storage cisterns are very liable to contamination.

4. Cisterns are more liable to frost than are service pipes.

5. Serious delays might occur in case of fire.

Quantity of Water Required.

The amount usually allowed per adult is—

Domestic.	Gallons.
Drinking	0·33
Cooking	0·75
Ablutions	5·00
House-washing	3·00
Clothes-washing	3·00
W.C.'s	6·00
Bath (28 gals. per wk.) . .	4·00
Waste	3·00
	25·08
Municipal.	
Streets, Fountains, Fires, Trades	5·00
Special manufactures . . .	5·00
Total per head of population daily =	35·08

The above quantity is an ample allowance for all needs; and is also sufficient to keep the sewers in good working order. In time of drought or other extraordinary shortage of water, the amount may of course have to be much reduced, but *should never fall below* 4 *gals. per head per diem.*

The following list will show the way in which several cities meet the requirements laid down by the above standards.

	Gals. per head daily.
London	35·4
Liverpool	23
Manchester	20
Edinburgh	36
Glasgow	55
Dublin	35
Paris	44
Berlin	22
St. Petersburg	49
New York	83
Rome	220

IV. Impurities of Water.

The following strata yield pure water—

1. Chalk.
2. Oolite.
3. Green sand.
4. Hastings sand.
5. New red and conglomerate sandstone.

Other strata are liable to contain an excess of chemical salts, *e.g.*, limestone waters contain calcium and magnesium carbonates and sulphates. Artesian well water frequently contains free NH_3 and excess of NaCl and Na_2CO_3.

From these considerations, we see that the impurities may be due to geological formation as well as to the animal and vegetable contamination or supply pipes, etc., as we should expect.

For practical purposes, the impurities may be grouped under three main heads—

1. Dissolved Gases.

O, N, CO_2, H_2S derived from the air or soil.

2. Dissolved Solids.

Chiefly NaCl, Na_2SO_4, Na_2CO_3, $CaCO_3$ (+ CO_2), $CaSO_4$, $CaCl_2$, and $MgCO_3$, these being derived from the geological formations. Also Pb, Zn, As, Cu, Mn, and Fe, which may occasionally be found in waters from a metalliferous stratum; while the first (Pb) may result from the use of lead cisterns and pipes.

Solvent action of waters on lead—

<table>
<tr><th>No Solvent Action.</th><th>Solvent Action.</th></tr>
<tr><td>1. Hard waters.
2. Free CO_2, if not in excess.
3. Silicated water.</td><td>1. Dissolved organic matter.
2. Peaty water c̄ free acid.
3. Dissolved chlorides.
4. Highly oxygenated.
5. Excess of CO_2.</td></tr>
<tr><td>Note.—The usual crust on lead pipes when the water is hard consists of the carbonates, sulphates, and phosphates of calcium, lead, and magnesium.</td><td>Note.—Examples of waters with solvent action on lead will therefore be:—water contaminated with sewage, soft peaty waters, rain water, deep-well water, and water containing acid sulphates.</td></tr>
<tr><td colspan="2">Note.—The following points will also influence lead absorption:—The water temperature, the water pressure, the intermittency or constancy of supply, the juxtaposition of other metals in joints, the age of the lead, and the purity of the lead.</td></tr>
</table>

The permissible amount of Pb is gr. $\frac{1}{20}$ per gal. (0·07 part per 100,000).

3. Suspended Solids.

These will include animal, vegetable, and mineral particles, trade refuse, and multitudinous micro-organisms.

Many, in fact the majority, of such solids may be innocuous, and all tend to oxidation and mechanical deposit.

A chemical, and sometimes a biological, analysis (*vide* next chapter) is generally necessary to determine the fitness of a water for human consumption.

We shall now consider the *micro organisms of water*.

The germs are derived (1) from the air and (2) from the soil. The upper four feet of soil are very rich in organisms; below 15 feet there are very few. Surface water will therefore contain most bacteria.

By the above two channels, organic débris, excrement, and specific-disease bacteria will reach water. All waters practically without exception contain micro-organisms, and therefore their actual presence signifies nothing.

Their quantity, also, need not necessarily be of importance.

The following list of micro-organisms (after Davies) will show the wide variation which may exist :—

Source.	*Organisms per c.c.*
Artesian well, Rangoon (Davies)	2
Boiled, distilled water (Koch)	4 to 6
Rain water, Montsouris (Miquel)	4·3
River Rhone, above Lyons (Roux)	75
Chelsea water mains (Parkes)	85
River Spree, filtered (Koch)	120
River Indus (Davies)	280
River Rhine, Cologne (Mærs)	20,680
River Spree, unfiltered (Koch)	125,000
River Seine, St. Denis (Miquel)	200,000
Crude Sewage, Barking (Houston)	3,899,259
Sewer water (Koch)	38,000,000

The point of real importance is to determine the *presence or absence of pathogenic bacteria*, or of organisms characteristic of sewage or animal pollution.

The discovery of any of the following pathogenic and non-pathogenic organisms may give a clue as to the source and contamination of the water—

Organism.	*Conclusion.*
M. ureæ *M. cinnabareus* *B. fluorescens liquefaciens* *B. erythrosporus* *B. mesentericus fuscus* *B. „ vulgatus*	Stagnant water.
B. proteus vulgaris *B. „ mirabilis* *B. fluorescens putridus*	Decomposing animal matter.
B. mycoides *Cladothrix* *B. subtilis* (spores) *B. mesentericus* (spores) *Streptococci*	Surface-soil water.
B. typhosus *S. choleræ* *B. coli communis* (if in large numbers) *B. enteritidis sporogenes*	Sewage pollution.

Other organisms, many of which are pathogenic, have been found in water. *B. anthracis* has been found in wells near infected sheep, and can live for several months. *B. tuberculosis* has been isolated from ditch-water, and has been found in sterilised water after 115 days. *B. diphtheriæ* can survive in darkened water for several weeks. *B. tetani* has been isolated from the Seine, the Dead Sea, and from some reservoir mud at Lyons.

As a rule, the ordinary aquatic bacteria are prejudicial to the pathogenic bacteria. Generally speaking, the latter will live longer in sterilised water, especially in the presence of a little organic matter.

V. Water-borne Disease.

The diseases carried by water are usually limited to three—*Cholera, Enteric Fever*, and *Epidemic Dysentery.*

The *characteristics of a water-borne epidemic* are:—

1. Sudden and localised outbreak.
2. Simultaneous cases in same house.
3. High attack rate.
4. Abbreviation of incubation period (?).

Cholera. That this disease is water-borne was pointed out by Snow in 1849.

Well-known examples are: the Broad Street pump (London) epidemic in 1854, and the Hamburg epidemic in 1892.

Enteric Fever. The water-borne origin was established by Flint (U.S.A.) and Carpenter in 1852.

Well-known examples are: the Guildford outbreak from an infected well in 1867, and the Modder River infection of British troops in South Africa in 1902.

Epidemic Dysentery. This is not the tropical or endemic dysentery (which is due to an amœba), but is an epidemic dysentery which may occur in any part of the globe, and is due usually to the *Shiga-Kruse bacillus*, or more rarely to one of the para-dysentery bacilli, *i.e.* *Lenz*, *Flexner-Strong*, or *Harris-Gay*.

An example of an epidemic is the infected well at Kaapsche Hoop (Transvaal) during the South African War in 1901.

Other pathological conditions due to water supply are—**Goitre, Diarrhœa, Lead Poisoning,** and **Entozoal Infection.**

The *avoidance of water-borne disease* is secured by—

$$\left.\begin{array}{l}\text{1. Boiling}\\ \text{2. Filtration}\end{array}\right\}\text{ of drinking water.}$$

Boiling, if it can be secured, is the safest of all methods. If not, filtration should always be carried out unless the water is above suspicion.

The **Drip-stone Filter** will remove gross impurities, but not micro-organisms.

The old-fashioned **Charcoal Filters** are useless, and merely form breeding-grounds for microbes.

The only two reliable filters are—(1) The **Berkefeld Filter,** which consists of a hollow candle of infusorial clay, through which the water percolates. (2) The **Pasteur-Chamberland Filter,** which is even better. It has one or more hollow candles of unglazed porcelain, made in varying degrees of fineness. Both the two latter require to be cleaned and boiled occasionally.

CHAPTER VII

WATER ANALYSIS

The analysis of water is of a threefold type.

Chemical Analysis, to determine the metals, acids, salts, etc. *Microscopical Examination* to determine the nature of sediment, suspended solids, etc., and *Biological Examination* to isolate and classify the micro-organisms which may be present.

CHEMICAL ANALYSIS.

Collection of Samples.

A glass-stoppered Winchester quart bottle should be used. It should be rinsed with strong H_2SO_4, and then washed with ammonia-free water until all trace of acid has disappeared.

In taking the sample the bottle should be rinsed out once with the water under examination. The bottle should then be filled just above the shoulder, the glass stopper replaced and tied down, and a label affixed stating the exact source, date and time at which the sample was taken.

As chemical changes soon occur, the analysis should be conducted as soon as possible after the sample has been obtained. If it is necessary to keep it, or to forward it to any great distance, it should be surrounded by ice.

Form of Report.

The Report should include the following points—

Turbidity.	
Colour.	
Taste.	
Smell.	
Reaction.	
Total solids	(quantitative).
Chlorides	"
Nitrates	"
Free NH_3	"
Albuminoid NH_3	"
Hardness, temporary and permanent.	
Oxygen absorbed.	
Nitrites (qualitative).	
Poisonous metals.	
Nature of sediment.	

Analysts unfortunately have no uniformity in the expression of their results. Some express their figures in grs. per gallon; others in parts per 100,000; others again in parts per 1,000,000.

On the Continent they are universally reported in *parts per* 100,000, and this should be adopted for purposes of comparison and uniformity.

NH_3, in order to record units instead of decimals, is sometimes expressed in parts per 1,000,000 and the rest of the report in parts per 100,000; there is, however, no necessity for this at all.

If it is wished to convert grains per gallon into parts per 100,000, they should be multiplied by $\frac{10}{7}$.

$$\underset{\text{(i. e. grammes per 100,000 c.c.)}}{\text{Parts per 100,000}} = \frac{\text{grs. per gallon} \times 10}{7}$$

or *vice-versâ*:—

Grs. per gallon = parts per 100,000 × 0·7

If the report is to be returned in parts per 100,000, 50 or 100 c.c. should be employed for the estimations whenever possible.

If however grs. per gallon are required, it will then be more convenient to use 70 c.c.; the reason for this being that 70 c.c. of water weigh 70,000 mg., and 1 gal. weighs 70,000 grs. Therefore 70 c.c. is a sort of miniature gallon wherein the mg. corresponds to the gr., and x mg. per 70 c.c. = x grs. per gallon.

The Examination.

1. COLOUR AND TURBIDITY.

Fill a 100 c.c. cylinder with some of the water; hold it over a sheet of white paper; look down the tube, and note the colour and turbidity observed.

Note.—A pure water should be colourless, or faintly bluish, and quite bright and clear. A yellowish or greenish tint is suggestive of pollution. Peaty water may have a brown tint. On the other hand, water contaminated with sewage may be quite bright and clear.

2. ODOUR.

Place 50 c.c. in a flask. Warm it slightly over a flame, or on the water-bath. Then cork tightly; shake vigorously. Remove the cork quickly and smell, noting down the result.

Note.—Pure water has no smell. If there is a smell after warming it will very likely mean pollution.

Some waters, however, which are quite drinkable, have a slight smell, *e.g.* a peaty water has a slight characteristic smell; boulder clay waters may smell slightly of H_2S; rain water has usually a faint smell.

On the other hand, again, a water totally unfit to drink may have no smell at all.

3. **REACTION.**

This should be tested with litmus paper.

NOTE.—Most drinking waters are neutral or faintly alkaline. Some moorland surface waters are acid—due to humic and ulmic acids—(*e. g.* the Sheffield supply from the Yorkshire moors) and such acid water may act on lead, iron and zinc.

4. **TOTAL SOLIDS IN SOLUTION.**

Allow any sediment to settle; and, while this is proceeding, clean a large platinum dish with HCl, wash it, dry it, and weigh it carefully.

100 c.c. of the clear water are now pipetted off and run into the weighed platinum dish.

The dish is then placed on the water-bath, covered with an inverted funnel, and evaporated to dryness.

It is then placed for half an hour in a water-oven, cooled in a desiccator, and then carefully weighed.

This weight, less the original weight of the empty dish, gives the weight of the total solids.

The dish is now taken and placed on an iron tripod over a Bunsen flame. The amount of charring should be noted as the ignition is proceeding.

The ignition is continued until a white residue remains, when the dish is cooled and re-weighed.

The difference between this final weighing and the second weighing will give the "loss on ignition," which represents roughly the organic matter present.

NOTE.—A good potable water when evaporated to dryness leaves only a very small white residue. (Permissible amount in a soft water = 40 grs. per gallon = 57 parts per 100,000 = 0·057 mg. in the 100 c.c. sample taken.)

If organic matter is present the residue may be brownish and will char on ignition, unless accompanied by much nitrates.

The residue of a peaty water will also char.

5. **HARDNESS.**

The hardness of water is of two kinds—**Temporary**, due to carbonates held in solution by dissolved CO_2;

and **Permanent,** due to calcium and magnesium sulphates and chlorides in solution.

In the examination for hardness we first estimate the *total* (including both temporary and permanent) hardness; we then get rid of the carbonates by boiling, and then make an estimation of the *permanent* hardness. The difference between these two will of course represent the *temporary* hardness.

The **rationale** of the process is as follows:—

A soap contains the sodium and potassium salts of one or more fatty acids. When the soap is shaken with water these salts pass into solution and are capable of forming a *lather*. If, however, this solution of a potassium or sodium soap is added to a solution of a calcium or magnesium salt, then an *insoluble* calcium or magnesium soap will be formed; and, on shaking, less lather will be formed in proportion to the amount of magnesium or calcium salts present.

We therefore have to make use of a **standard soap solution** of such strength that each c.c. will precipitate 0·001 gramme of $CaCO_3$. This is made by dissolving some sodium oleate in methylated spirit and water, gauging the amount necessary to cause a permanent lather with distilled water and with a standard calcium solution, and then bringing the soap solution to the standard strength required.

Modus Operandi.

Put 50 c.c. of the sample on the boil, which should be continued until its volume is reduced to $\frac{1}{3}$.

NOTE.—This expels the CO_2, and precipitates the carbonates which cause the temporary hardness.

Then fill a burette with the standard soap solution, recording the height.

Take a "hardness" bottle (*i.e.* glass-stoppered, of about 125 c.c. capacity) and pipette in 50 c.c. of the sample water.

Put the bottle under the burette, run in 1 c.c. soap solution, replace the stopper and shake.

Continue this process (1 c.c. at a time) until a permanent lather is secured, which remains after the bottle has been laid on its side for two minutes.

The number of c.c. soap solution used (less 1 c.c.) will give the number of milligrammes of Ca and Mg (expressed as $CaCO_3$) in each 50 c.c. of the sample, and the number of grammes per 100,000 can easily be calculated.

The result is also sometimes expressed as "degrees of Clark" *i.e.*, as the number of c.c. of the standard soap solution used.

If more than 9 c.c. of the soap solution are required the precipitated calcium and magnesium soaps will make the determination of the lathering point very difficult.

A new observation should therefore be made after diluting 25 c.c. of the sample with 25 c.c. of distilled water.

The sample which had been boiling will now be ready to be tested. It should be filtered and made up to 50 c.c. with distilled water; then put in a "hardness" flask, and the soap determination made as in the case of the other sample. This will give the *permanent hardness*, and if the permanent hardness be deducted from the total hardness, we get the *temporary hardness*.

It is sometimes required to know how much of the hardness is due to lime (Ca) as opposed to Mg salts. In this case the total hardness is estimated as before. In another sample the lime is precipitated with ammonium oxalate, filtered, and the filtrate estimated for hardness, which will give the Mg. The Mg hardness, deducted from the total hardness = Lime.

NOTE.—The scale for water is—

Not exceeding	4°	= very soft.
,, ,,	9°	= soft.
,, ,,	14°	= hard.
,, ,,	24°	= very hard.

The softer waters are best suited for domestic purposes.

The *permanent* hardness is the most objectionable feature.

The permissible amounts should be 15° of total hardness and 5° of permanent hardness.

6. **CHLORINE.**

The **rationale** of an analysis for chlorides is as follows :—

If a silver nitrate solution is added to an alkaline solution of a chromate, reddish-brown silver chromate is formed. But if the alkaline chromate solution contains a solution of a chloride, then the silver nitrate will first combine with the chloride to form white silver chloride, and not until the whole of the chloride has been used up will the silver begin to combine with the chromate.

We therefore use a little chromate solution as an indicator, and titrate with a **standard $AgNO_3$ solution.**

The making of this standard solution (as of other standard solutions) is easy.

We want 1 c.c. of the standard solution to precipitate 1 milligramme of Cl (*i.e.* 1 litre to precipitate 1 gramme). The molecular weight of $AgNO_3 = 169·7$; the molecular weight of $Cl = 35·5$. Therefore, the amount of $AgNO_3$ that we must dissolve in 1 litre of water is $\frac{169·7}{35·5} = 4·78$ grammes.

Such solution is $\frac{N}{1}$ $AgNO_3$ solution.

The **modus operandi** is as follows :—

A burette is thoroughly cleaned, filled with the $\frac{N}{1}$ $AgNO_3$ solution ; a few drops are run out to fill the nozzle, and the height is recorded.

Fifty c.c. of the water sample are now run into a glass beaker, which is stood on a piece of white filter paper under the burette.

A little K_2CrO_4 solution is added and stirred in.

The silver solution is now run in, one or two drops at a time.

NOTE.—See that the solution is alkaline.

Where the drop falls in, a red-brown coloration results from the formation of silver chromate; but this coloration almost instantaneously disappears on stirring, owing to the combination of the silver with the chloride of the sample.

As the titration proceeds, the evanescent coloration does not disappear so rapidly, thus showing that the chloride is nearly used up. This is a warning to proceed very slowly with the addition of the $AgNO_3$.

When the red-brown colour is permanent, on stirring, the number of c.c. which have been used out of the burette should be noted (say x c.c.).

Now :—

$$1 \text{ c.c. } \frac{N}{1} AgNO_3 = 0{\cdot}001 \text{ gramme Cl}$$

$$\therefore x \text{ c.c.} = 0{\cdot}00x \text{ gramme Cl}$$

But this amount is contained in 50 c.c. of the sample.

$$\therefore 0{\cdot}00x \times 2000 = \text{grammes Cl per } 100{,}000$$

If it be desired to express the result in terms of NaCl instead of Cl, then

$$NaCl = Cl \times \frac{\text{Mol. Wt. NaCl}}{\text{Mol. Wt. Cl}} = Cl \times \frac{58{\cdot}5}{35.5}$$

NOTE.—All waters contain chlorides. The permissible amount is sometimes said to be 5 parts per 100,000, but this figure is not of much importance, and a high chlorine result is not, *per se*, of necessity bad.

If a high chlorine figure be combined with an excess of nitrates, it will generally indicate sewage pollution.

If, in addition to high chlorides and nitrates, there is also organic matter, we should infer that the pollution is recent and that the water is very dangerous.

7. POISONOUS METALS.

This is not a toxicological analysis, and therefore we need not go through the regular tables for the detection of metals.

The poisonous metals with which we are now concerned are those which may have been taken up by the water from vessels in which it has been stored or pipes through which it may have passed. These are lead, iron, copper, and zinc.

Modus operandi.

Pipette 50 c.c. of the sample into a porcelain basin. Add NH_4HS to the sample—

(*a*) *White ppt.* = Zn. (Confirm by adding to original solution in test-tube some CH_3COOH (acetic acid) and K_4FeCy_6. White ppt. = Zn.)

(*b*) *Dark colour or ppt.* = Fe, Pb or Cu.

If (*b*) then divide into 2 parts.

A.

Add HCl.

Ppt. sol. = Fe.

(Confirm by adding HCl and pot. ferrocyanide to orig. sol. Blue = Fe.)

If ppt. insol. then proceed with B.

B.

Add KCN.

Ppt. sol. = Cu.	Ppt. insol. = Pb.
(Confirm by adding CH_3COOH + K_4FeCy_6 to orig. sol. Red = Cu.)	(Confirm by adding K_2CrO_4 to orig. sol. Yellow = Pb.)

NOTE.—*Copper* is rarely met with.

Zinc is derived from galvanised pipes, and is objectionable, though not as a rule followed by serious effects if only present in traces.

Iron may occur as a natural constituent of the water or may be taken up by pipes. It gives an inky taste to the water, is bad for washing clothes, and may cause constipation.

Lead. This is a serious impurity. No trace of lead is permissible. Waters capable of taking up lead will be very soft, highly oxygenated, or will contain ammonia or nitrites. A water capable of attacking lead will contain amounts varying according to the time it has been in contact with the pipe, etc.

Quantitative iron is measured by Nesslerising against a standard iron solution a sample of water coloured by the addition of $(NH_4)_2S$ in the presence of NH_3 and NH_4Cl.

Quantitative lead is measured by Nesslerising against a standard lead solution a sample coloured by addition of CH_3COOH and H_2S.

8. **NITRITES.**

The examination is usually only qualitative.

1st Method—Starch Iodide.

The **rationale** of this reaction depends on the liberation of nitrous acid from a nitrite by means of sulphuric acid.

The free nitrous acid in turn liberates I from KI, and the free I in the presence of starch gives a blue colour.

The **modus operandi** is as follows:—

Two Nessler glasses are taken. Into the one pipette out 50 c.c. of the sample. Into the other, 50 c.c. of distilled water as a control.

To both glasses a few c.c. of KI solution and a few c.c. of starch solution are added.

Add to each glass a few drops of H_2SO_4 dil., and quickly look through them against a white surface. An immediate blue colour will indicate the presence of nitrites.

In the presence of unstable organic matter, *nitrates* will occasionally give the same reaction after a short interval.

2nd Method—Greiss.

The **rationale** of this method is, that the colourless solution known as Diamido-benzol (or Meta-phenylene-diamine) will give rise to a brown compound known as

triamido-azo-benzol (Bismark brown) when acted on by nitrous acid. If therefore we have a solution containing nitrites and liberate nitrous acid by means of H_2SO_4, the coloration will be obtained on the addition of the diamido-benzol.

It is by this method that a quantitative analysis of nitrites is performed.

The **modus operandi** is as follows:—

Take two Nessler glasses. In one of them pipette 50 c.c. of the sample; and in the other 50 c.c. of distilled water as a control.

To each glass add a few c.c. of H_2SO_4 dil.

To each glass then add a few c.c. of the diamido-benzol and allow to stand for a quarter of an hour.

A yellowish-brown coloration of the sample will indicate the presence of nitrites.

NOTE.—The presence of nitrites in a water is immediately suspicious.

If a trace of metals has been found in the water, the nitrites may mean nothing, for metals may have a reducing action on nitrates. Otherwise, the slightest trace should condemn a water.

9. NITRATES.

The **rationale** of the method depends on the fact that, in the presence of nitrates, phenol-sulphonic acid is converted into picric acid (or tri-nitro-phenol); and that the ammonium salts of the latter acid are of an intense yellow colour.

$$\underset{\text{Phenol-sulphonic acid.}}{C_6H_4(OH)SO_3H} + 3HNO_3 = \underset{\text{Picric acid.}}{C_6H_2(OH)(NO_2)_3} + H_2SO_4 + 2H_2O$$

In order to obtain a quantitative result, comparison is made with a **standard** KNO_3 **solution.**

In this we require—

1 c.c. = 0·001 gramme KNO_3 = 0·000014 gramme N.

The M.W. of KNO_3 = 101·1, therefore we dissolve 101·1 grammes in 1 litre of water.

The **modus operandi** is as follows:—

In a porcelain basin evaporate 10 c.c. to dryness on a water-bath.

At the same time in another basin similarly evaporate 1 c.c. of the standard nitrate solution.

When evaporated, add to *each* of the above 1 c.c. of Phenol-sulphonic acid.

Stir both with a glass rod.
Dilute each with a little water.
Filter each into Nessler glasses.
Add to both strong NH_3 in excess.[1]
Make each up to 50 c.c.
Nesslerise.

In the control, 50 c.c. of the Ammonium Picrate $= 1$ c.c. $\frac{N}{1}$ KNO_3 = 0·001 gramme KNO_3, and by colour testing the amount in the sample can easily be determined.

NOTE.—Nitrates are the last stage in the oxidation of organic matter, and are chiefly derived from manure and sewage.

In themselves they are harmless, but if combined with organic matter they indicate dangerous pollution.

No definite limit can be laid down, since a mere trace might indicate pollution in some waters, while in others (such as agricultural district subsoil waters) a larger amount may be compatible with a drinkable water.

1·5 parts per 100,000 will in any case cause the gravest suspicion.

10. FREE AMMONIA.

When organic matter in water decomposes, the N is first converted into NH_3, which is later oxidised into nitrites and nitrates.

[1] This converts the picric acid into ammonium picrate ($C_6H_2(NO_2)_3ONH_4$)—a dangerous body used as a constituent of some explosives.

Some of this NH_3 is combined with carbonic or nitric acids or other easily decomposable substances. Such NH_3 is termed *Free, or Saline Ammonia.* It is found that if water be distilled, $\frac{2}{3}$ of this free NH_3 will come over with the first 50 c.c. of distillate, and that the *whole* will come over in the first 150 c.c.

After this free NH_3 has been got rid of, there exists in contaminated water some nitrogenous organic matter the N of which can be converted by potassium permanganate (in the presence of an alkali) into NH_3; NH_3 so derived is known as *albuminoid ammonia.*

The **rationale** of the process is as follows:—*Nessler's Solution.* A solution of Mercuric Chloride ($HgCl_2$) (17 grammes to 300 c.c.) is added to a solution of KI (35 grammes in 100 c.c.) until a permanent precipitate of HgI_2 is formed. This mixture is diluted to 1000 c.c. with a solution of NaOH (200 grammes to 1000 c.c.), which redissolves the precipitate.

More of the $HgCl_2$ solution is added until a permanent precipitate is again formed, when it is put in a glass-stoppered bottle and allowed to stand for 24 hours. The clear fluid is used from time to time as required, and is known as **Nessler's Reagent.**

If some of this Nessler's reagent is added to water containing the faintest trace of NH_3, a di-mercurammonium iodide is formed, which possesses a browny-yellow colour. Greater amounts of NH_3 will send down the same salt as a precipitate.

$$2(2KI.HgI_2) + 3KOH + NH_3 = NHg_2I.H_2O + 7KI + 2H_2O.$$

This reaction serves as a very delicate colorimetric test; and the quantities of NH_3 in a sample can be fairly accurately determined by comparing the colour of the sample plus Nessler, with that of a known **standard ammonium chloride** solution plus Nessler, such process being termed "*Nesslerisation.*"

The standard solution of NH_4Cl should contain 1 gramme of NH_3 per litre.

$$\frac{\text{Mol. wt. } NH_4Cl}{\text{Mol. wt. } NH_3} = \frac{53 \cdot 5}{17} = 3 \cdot 147 \text{ grammes per litre}$$

Such $\frac{N}{1}$ solution will equal one milligramme NH_3 per c.c., but will be too strong for the Nessler tests. We therefore make a $\frac{N}{100}$ solution by adding 10 c.c. of the $\frac{N}{1}$ solution to 990 c.c. of ammonia-free water.

Then 1 c.c. = 0·00001 gramme NH_3.

The **modus operandi** is as follows:—

A 32 oz. stoppered retort will be necessary, as also a Liebig's condenser, some indiarubber tubing, 12 Nessler glasses, a 2 c.c. pipette, some Nessler's reagent, a burette with $\frac{N}{100}$ NH_4Cl, and some ammonia-free water.

1. The retort and condenser are cleaned out with HCl conc. and finally washed well with ammonia-free water.

2. They are then fixed up with tripod and clamps, putting the nozzle of the retort into the wider end of the condenser, and making the joint tight with a piece of rubber tubing.

3. Connect the condenser with a tap and sink, in such a way that the liquid runs in below and runs out above.

4. Put into the retort 500 c.c. of the sample, together with a little ammonia-free Na_2CO_3 and a little pumice or small glass rods to prevent "bumping."

5. Light a Fletcher burner and place under the retort.

6. Turn on the water through the condenser.

7. Let the condenser exit be inserted into a Nessler glass.

8. When 50 c.c. have been distilled over into the Nessler glass, remove it and place a fresh glass in position.

9. Now test the removed 50 c.c. as explained below.

10. The next 50 c.c. should be tested, and so on until no NH_3 is found.

As a rule, all the NH_3 will come over in the first three distillates, and none will be found in the fourth.

11. The remainder of the sample is used to determine the albuminoid ammonia (*q.v.*).

Method of Nesslerising the above distillates—

(*a*) Take three clean Nessler glasses, run into the first 1 c.c. of the $\frac{N}{100}NH_4Cl$ solution, make up the amount to 50 c.c. with ammonia-free water.

(*b*) Run into the second 3 c.c. and make up to 50 as before.

(*c*) Run into the third 5 c.c. and make up to 50 as before.

(*d*) Into each of these three glasses pipette 2 c.c. of Nessler's reagent, shake and allow to stand for a few minutes. You will now have three standard colorations to work with.

(*e*) Now take the first distillate which came over; add to it 2 c.c. of Nessler's reagent; shake and compare the colour with the colour of the three standards by holding the glasses a little above a white surface, and looking down at the white surface through the liquids.

If the sample exactly matches in colour, say the standard made with 3 c.c. of the $\frac{N}{100}NH_4Cl$ solution, then we know that this distillate contains $3 \times 0{\cdot}00001$ gramme NH_3.

If it does not exactly match either of the three

standards, then some of the sample is removed by pipette until one of the standard tints can be matched, and by a simple calculation the NH_3 can be measured.

(*f*) The second, third and (if necessary) fourth distillates are tested in a similar way—the results (in grammes of NH_3) of all these are added together; and, since all the free NH_3 has come over, the total will be the total free NH_3 in 500 c.c. of the sample. By multiplying this figure by 200 we get "parts per 100,000."

NOTE.—Most waters contain a trace of ammonia. But the permissible amount is only 0·005 part per 100,000.

Rain-water generally contains some perceptible amounts.

If the water contains any metals they are very likely to reduce any nitrates present, and cause an excess of ammonia.

If no metals are present and the water is not rain-water, then the NH_3 is very probably derived from decomposing organic matter, and should be looked on with much suspicion.

If over the permissible amount and in conjunction with excess of Cl, fœcal contamination is probable.

11. ALBUMINOID AMMONIA.

During the distillation of the free NH_3, 50 c.c. of an *alkaline permanganate solution* is added to 150 c.c. of ammonia-free water, and the whole is boiled till the bulk is reduced to 100 c.c. in order to distil off the free NH_3.

NOTE.—This alkaline permanganate solution is made by dissolving 8 grammes of $KMnO_4$ and 200 grammes of NaOH in 1,100 c.c. of distilled water, and boiling till the bulk is reduced to 1,000 c.c.

The 100 c.c. of boiled alkaline permanganate is then added to the balance of the water sample which remains in the retort after the distillation for free NH_3.

The stopper is replaced and the distillation recommenced.

The distillate is collected in Nessler glasses in amounts

of 50 c.c. just as was done in the distillation for free NH_3.

Each 50 c.c. is Nesslerised and the amounts recorded, and the totals finally added up and reduced to parts per 100,000.

The organic matter takes some time to be reduced, and does not necessarily distil over in the first 150 c.c. as it did in the case of the free NH_3.

If there is excess of organic matter, NH_3 may be detected in distillate after distillate until the retort is nearly dry. If this occurs 100 c.c. or more of ammonia-free water must be put into the flask and the distillation continued.

Note.—Albuminoid ammonia has quite a different significance to "free NH_3," and does not necessarily indicate fœcal contamination.

If the NH_3 comes over slowly a vegetable origin is probable; if fast an animal origin.

The permissible amount is 0·01 part per 100,000. In peaty and other vegetable waters the amount may be much higher than this without detriment, but in this case the Cl reading will be low.

12. OXYGEN ABSORBED.

This process is carried out to get an idea of the amount of organic matter present.

The **rationale** is as follows:—In the presence of H_2SO_4 organic matter is oxidised by pot. permanganate

$$K_2Mn_2O_8 + 3H_2SO_4 = K_2SO_4 + 2MnSO_4 + 3H_2O + 5O$$

Now $K_2Mn_2O_8$ will liberate I from KI ($K_2Mn_2O_8 + 8H_2SO_4 + 10KI = 6K_2SO_4 + 2MnSO_4 + 8H_2O + 5I_2$).

If therefore to a solution containing organic matter, which has been treated with $K_2Mn_2O_8$ and H_2SO_4, we later add some KI, just so much $K_2Mn_2O_8$ as has not been previously used in oxidising the organic matter will act on the KI.

The amount of I liberated will therefore be a guide

to the amount of *unused* $K_2Mn_2O_8$, and consequently to the amount of organic matter in the sample.

The amount of free I can readily be ascertained by titrating with the sodium thiosulphate ("hypo") which converts the I into NaI.

The free I will have a blue colour in the presence of starch. When this blue colour has disappeared during the titration with "hypo," then we know that all the free I has gone.

$$2Na_2S_2O_3 + I_2 = 2NaI + Na_2S_4O_6$$

The **modus operandi** is as follows :—

(*a*) Take 2 clean stoppered bottles of 300 c.c. capacity.

(*b*) Into one of these put 250 c.c. of the sample ; into the other 250 c.c. of distilled water.

(*c*) Bring both bottles to 80° F.

(*d*) Run into both—

10 c.c. standard $K_2Mn_2O_8$, and
10 c.c. (1 in 3) H_2SO_4.

The making of the standard solutions is as follows—

Standard Potassium Permanganate.

$$\underbrace{K_2Mn_2O_8}_{316} + 3H_2SO_4 = 2MnSO_4 + 3H_2O + \underbrace{O_5}_{80}$$

So that 316 grammes yield 80 grammes O.

It has been found best to work with a standard of **10 c.c. = 0·001** gramme **O**.

Therefore 1 litre of the standard solution must contain 0·1 gramme O.

To allow of this we must put in each litre of water

$$\frac{316}{80} \times 0{\cdot}1 \underset{K_2Mn_2O_8}{\text{gramme}} = 0{\cdot}395 \underset{K_2Mn_2O_8}{\text{gramme}}$$

Standard Hypo Solution.

7·75 grammes of sod. thiosulphate are dissolved in 1 litre of water, giving a strength

1 c.c. = 0·00025 gramme O.

(*e*) Keep both on water-bath at 80° F. for 3 hours.

(*f*) Cool.

(*g*) Add to each 10 c.c. KI solution. (The pink colour of the permanganate is now replaced by yellow.)

(*h*) Fill burette with standard thiosulphate and read height.

(*i*) Run this thiosulphate slowly into both bottles till the yellow colour gets fainter.

(*j*) Add to each 10 c.c. starch solution. (The colour now becomes dark blue.)

(*k*) Continue the titration very slowly and carefully, with stirring, until the blue colour vanishes.

(*l*) Calculate the number of c.c. of thiosulphate used in each case.

Calculation.

Say the sample took x c.c. of hypo to decolorise it.

Say the control took y c.c.

Then

y c.c. of hypo = 10 c.c. $K_2Mn_2O_8$ = 0·001 gramme available O.

But—

(y c.c. − x c.c.) = amount of O absorbed by the sample.

Therefore—

as y c.c. = 0·001 gramme O,

$$\therefore \quad (y - x \text{ c.c.}) = \frac{y - x \text{ c.c.}}{y \text{ c.c.}} \times 0{\cdot}001 \text{ gramme.}$$

But ($y - x$ c.c.) = amount O absorbed by sample.

$$\therefore \quad \text{Amt. O absorbed} = \frac{y - x}{y} \times 0{\cdot}001 \text{ gramme.}$$

Now as 250 c.c. of water were taken we express the answer thus—

$$\text{Parts per } 100{,}000 = \frac{y - x}{y} \times 0{\cdot}001 \times 400$$

Note.—If free NH_3 and Cl are small or absent, then organic matter shown by this test is probably of vegetable origin and more or less harmless.

Otherwise 0·1 part per 100,000 is the highest permissible amount.

BACTERIOLOGICAL EXAMINATION.

This is a very difficult and complicated question, of which the barest outline can here be given.

The information is of three kinds.

(1) The number of micro-organisms present.
(2) The detection of germs suggestive of sewage contamination.
(3) The isolation of pathogenic bacteria.

The **collection of samples.**

This should be in glass-stoppered bottles sterilised at 150° C. for three hours, and the stoppers then tied down with oiled silk. The bottle should be held below the surface of the water under examination, before the stopper is removed, and the stopper quickly replaced and tied down.

The examination should be made at the earliest possible moment. If the samples are to be sent to any distance, the bottles should be packed in ice.

1. QUANTITATIVE EXAMINATION.

Some ordinary sterilised tubes of gelatin and of agar will be required, as well as some sterile Petrie dishes.

The former are liquefied by being placed in warm water.

By means of 1 c.c. pipettes (graduated in $\frac{1}{100}$) sterilised and plugged with cotton wool, both agar and glycerine tubes are (with ordinary water samples) inoculated respectively with 0·1, 0·2, 0·3, 0·4, 0·5 c.c. of the sample.

With bad waters dilution will be necessary.

As each tube is inoculated, it should be well mixed by rotating between the palms of the hands, and then quickly poured out with suitable precautions into a sterile Petrie dish, which should be labelled with a glass pencil.

The dishes are then solidified as rapidly as possible and incubated—the agar at 37° C. and the gelatin at 20° C.

The principle of the procedure is that each micro-organism gives rise to a colony which is easily seen.

The number of colonies visible to the naked eye, or by a magnifying glass, on the 2nd or 3rd day should be noted, and reduced to terms of a c.c. But the report should state whether the result refers to naked eye or magnified observation, and whether on the 2nd or on the 3rd day.

They are best counted against a dark background, the area being divided up by lines on the plate itself.

NOTE.—A pure supply may give 50 to 500 per c.c.

Satisfactory filtration should not show more than 100.

The agar plates which are incubated at 37° C. will not show so many colonies as the gelatin, since most water organisms are suppressed at that temperature.

On the other hand gelatin is very hard to use in the tropics; and moreover many of the water organisms liquefy that medium.

2. SEWAGE CONTAMINATION.

A. Parietti's method.

B. coli communis and *B. typhosus* and other fœcal organisms grow in a broth to which has been added 0·05 to 0·15 per cent. carbolic acid, by which most water organisms are inhibited.

A stock solution is made by adding C_6H_5OH 5 grammes, and HCl 4 grammes, to 100 c.c. distilled water. If 0·1, 0·2 and 0·3 c.c. of this stock are added to 10 c.c. broth tubes they will contain 0·05, 0·1 and 0·15 per cent.

One c.c. of the sample is added to these, with ordinary precautions, and then incubated at 37° C. for 24 hours.

Polluted waters will cause a turbidity in that time. Such tubes should be "plated" (sec. art.) and subcultured for identification.

B. **MacConkey's method**

is based on a bile-salt glucose peptone litmus medium suggested by MacConkey and Hill, in which suggestive micro-organisms can grow—some of which ferment, forming acid and gas, others acid and no gas; and others again merely a turbidity.

A concentrated stock solution is prepared with sod. taurocholate 15 grammes; peptone 60 grammes; glucose 15 grammes; litmus to colour deeply, and 1 litre distilled water, the whole being boiled and filtered.

(*a*) Large test-tubes (8″ × 1″) are filled with 30 c.c. of the above stock, a small inverted Durham's tube is introduced, the tubes are plugged and sterilised for 15 minutes at 100° C. on three successive days.

(*b*) Ordinary test-tubes (6″ × $\frac{3}{4}$″) also with Durham's tubes, are filled with 6.6 c.c. of the stock and 3·4 c.c. distilled water and sterilised as above.

(*c*) Other test-tubes of the same size are filled with 5 c.c. stock and 5 c.c. distilled water, Durham's tubes, and sterilised as above.

(*d*) Further ones are filled with 3·4 c.c. stock, and 6·6 c.c. distilled water and sterilised as above.

When we are ready for the examination we put 50 c.c. of the water sample into the tubes (*a*), and incubate at 42° C. for 48 hours.

We put 10 c.c. of the water samples into tubes (*b*) and incubate as above.

Then 5 c.c. of the water sample into tubes (*c*) and incubate as above.

Finally 2 c.c. of the water sample into tubes (*d*) and incubate as above.

The organisms which merely cause turbidity are not of fœcal origin and have little hygienic significance.

Those which produce acid and gas, or acid only, are probably caused by intestinal bacteria; and are generally found together.

If no acid or gas is formed it is unnecessary to examine the samples further.

Acid and Gas.	Acid only.
B. coli communis	B. typhosus
B. acidi lactici	B. dysenteriæ
B. lactis ærogenes	B. para-dysenteriæ
*B. proteus	*S. choleræ
B. para-coli	*B. prodigiosus
B. para-typhosus	Streptococci
B. enteritidis (Gärtner)	*Staphylococci

Those tubes which show acid and gas will have to be "plated" and "subcultured" to differentiate the species.

* Liquefy gelatin.

CHAPTER VIII

FOOD

By food we understand those substances capable of absorption by the alimentary canal for purposes of growth or nutrition, or for the production of energy and heat.

The *legal definition* under the "Sale of Food and Drugs Act, 1899," is: "Every article used for food or drink by man other than drugs or water, and any article which ordinarily enters into and is used in the composition or preparation of human food, and also flavouring matters and condiments."

We may *classify* food constituents under the following heads:

1. Albuminates.
2. Albuminoids.
3. Extractives.
4. Hydrocarbons (fats).
5. Carbohydrates.
6. Organic acids.
7. Mineral salts.
8. Water.

1. Albuminates.

These are present in most animal and vegetable foods. They include the following: *Albumin, casein, globulin, fibrin, myosin, syntonin, glutin, legumin.* They consist

chemically of the following substances in percentage proportion:

$$C = 54, O = 22, N = 16, H = 7, S = 1$$
$$(N : C :: 2 : 7).$$

They are converted by the gastric and pancreatic juices into soluble peptones which are thus absorbed.

They are coagulated by heat, acids, and alcohol.

They are essential for the maintenance of life; they nourish the nitrogenous tissues; they provide material for growth and repair; they furnish oxidisable matter for the production of heat and energy, and the surplus is excreted as urea, uric acid, creatinin, leucin, and tyrosin.

2. **Albuminoids**

Are found in animal and vegetable foods, as *chondrin*, *elastin*, *fibroin*, *gelatin*, *keratin*, *mucin*, *neuclein*, *ossein*, and *spongin*. *Chemically* they consist of N, C, H, O, and sometimes S—

$$N : C :: 2 : 5{\cdot}5$$

They are much like the albuminates, but are soluble in hot water.

They do not aid much in processes of growth and repair, but provide oxidisable matter for the production of heat and energy.

The metabolic products resemble those of the albuminates.

3. **Extractives.**

They are found in small quantities in animal and and vegetable tissues.

They comprise *kreatin*, *kreatinin*, *karnin*, *xanthin*, and *aspargin*. *Chemically* they contain C, H, N, and O.

They are soluble in hot water.

They occur in meat juice, and their function is probably to stimulate the flow of gastric juice and aid digestion.

Their metabolic products are urea, CO_2, and water.

4. **Hydrocarbons.**

These are derived from animal and vegetable tissues. They comprise—

Butyrine—C_3H_5 $(C_4H_8O_2)_3$, contained in rancid butter and human sweat;
Olein—C_3H_5 $(C_{18}H_{33}O_2)_3$, a liquid occurring in olive oil;
Stearin—C_3H_5 $(C_{18}H_{35}O_2)_3$, a solid fat occurring in beef and mutton suet;
Palmitin—C_3H_5 $(C_{16}H_{31}O_2)_3$, a solid fat present in palm oil.

Human fat is a mixture of palmitin, stearin, and olein. *Chemically* they consist of C, H, and O, being compounds of the radicle "glyceryl" (C_3H_5) with the higher fatty acids.

They are unacted on by the saliva and gastric juice, but are emulsified by the pancreatic juice and bile, and are taken up by the lacteals of the small intestine. Those of lower melting point are better absorbed.

They have a double function in making body-fat, and in providing oxidisable material for the production of heat and energy.

Their metabolic products consist of glycerine and the fatty acids, and finally of CO_2 and water.

5. **Carbohydrates.**

They chiefly occur in the vegetable kingdom, and to a small extent in the animal. They comprise—

(*a*) Mono-saccharides—$C_6H_{12}O_6$, e.g. *dextrose*, *levulose*, and *glucose*, which are found in fruits,

seeds, roots, and honey. They are directly fermentable by yeast into alcohol and CO_2:

$$C_6H_{12}O_6 + \text{yeast} = 2C_2H_5OH + CO_2$$

and by bacteria into lactic acid:

$$C_6H_{12}O_6 = 2CH_3CHOH, COOH$$

(*b*) Di-saccharides—$C_{12}H_{22}O_{11}$, e.g. *sucrose* (cane sugar), *lactose* (milk sugar), and *maltose* (malt sugar), which are found in sugar-cane, milk, fruit, etc. They are only fermentable by yeast and bacteria after "inversion."

(*c*) Polysaccharides $(C_6H_{10}O_5)_n$, e.g. *starch* and *cellulose*. They are inverted to maltose by saliva ptyalin and by bacteria, but are not directly fermentable by yeast.

The carbo-hydrates are converted into glucose in the intestine, and from thence conveyed to the liver to be stored as *glycogen*.

The glycogen is used by the muscles, and supplies heat and energy.

They help to determine the alkalinity of the blood, and probably to a small extent help to form fat.

6. Organic Acids.

These are chiefly derived from fruits and vegetables. They comprise—

Acetic acid—CH_3COOH, the acid of vinegar;
Citric acid—$(CH_2COOH)_2$, CHO, COOH, present in lemons, currants, gooseberries, raspberries, etc.;
Lactic acid—CH_2OH, CH_2, COOH occurring in the fermentation of the sugars;
Malic acid—C_2H_3OH $(COOH)_2$, occurring in

apples, pears, cherries, mountain-ash berries, and rhubarb;

Oxalic acid—COOH, COOH, which occurs as potassium and calcium salts in rhubarb, etc.;

Tartaric acid—$(CHOH)_2$, $(COOH)_2$, which occurs as an acid potassium tartrate in grapes, tamarinds, pine-apples, etc.

They are converted by the body into carbonates, and thus serve to maintain the alkalinity of the blood.

7. **Mineral Salts.**

They are found in animal and vegetable tissues.

They exist chiefly as NaCl, phosphates of lime, potash, soda, and magnesia, as sulphates, etc.

Most of the phosphates are excreted unchanged.

Potash salts are used by the red corpuscles and muscles; soda salts by the intercellular fluids; iron supplies hæmoglobin; the chlorides help to form the HCl of the gastric juice.

Having now classified the constituents, we can consider the various foodstuffs of commerce.

COMPOSITION OF FOODSTUFFS.

(A) **Animal.**

1. **Meat.**

This consists roughly of—

Water	75 per cent.
Proteid	20 ,,
Fat	5 ,,
Acids and salts . . .	traces

The proteids comprise myosin, albumin, hæmoglobin, etc.; but myosin is the chief of these, and is really a globulin soluble only in saline or dilute acid solutions. It results from the muscular coagulation of *rigor mortis,* which is due to the presence of sarco-lactic acid.

Of the total proteids, about 13 % are made use of by the body.

The amount of *fat* will of course vary according to the species and nutrition of the animal. It is a mixture of oleates, palmitates, and stearates. In pork the former predominates, in beef the palmitates, and in mutton the stearates.

The chief *mineral salt* of meat is *potassium phosphate*, with small quantities of the chlorides and other salts of calcium, sodium, and magnesium.

The *extractives* of meat are kreatin, kreatinin, xanthin taurin, sarkin, and urea. As usually sold, *bone* usually equals one-fifth of the meat, and must be so allowed for in calculating dietetic values. The constituents of bone are: salts, water, gelatin, and fats.

Fish-meat resembles animal meat, except that there is more gelatin and water, and less albuminate and extractive.

Salt Meat has only $\frac{2}{3}$ the nutritive value of fresh meat, since brine dissolves out the myosin and other important constituents.

2. **Eggs.**

A hen's egg usually weighs 2 oz., of which the shell is 10 % by weight; the white, 60 %; the yolk, 30 %.

Ducks' eggs are richer in fat than hens' eggs.

Eggs are a convenient and concentrated article of diet.

The "white" contains *proteid* (egg albumin), *salts* and *water*.

The "yolk" contains *water*, *fat* (palmitin, stearin, and olein), *proteids* (vitellin and nuclein), a *glucoside* (cerebrin), and *organic and inorganic mineral compounds* (cholesterin, phosphoric acid, lime, iron, etc.).

Eggs can be conveniently preserved by coating the shell to exclude the air.

Their freshness can be determined by dissolving 2 oz.

common salt in a pint of water. Good eggs will sink in such solution; stale or bad ones will float.

3. **Milk.**

Milk is an excellent food, and forms the chief diet of infants. It is an emulsion of fat with proteids, carbohydrates and salts in solution with water.

The *proteids* are casein and lact-albumin, the former chiefly contributing to the white opalescent appearance of milk. The casein is kept in semi-solution by calcium phosphate, and does not coagulate on heating.

The *carbohydrate* is lactose (milk sugar)—a hard gritty solid, dextro-rotatory, and with a slightly sweetish taste. Lactic acid fermentation is brought about by the *B. lactis.*

Fat is present as a fine emulsion, much of which rises to the surface on standing, and constitutes **cream**, and the remaining milk is known as **skim milk**, which contains about 1 % fat.

If the cream is removed by a "separator," the separated milk has practically no fat left.

The *salts* in milk are chiefly calcium, sodium and potassium phosphates, and calcium citrate.

Water is present to the extent of 87 to 88 %.

Human milk contains less casein and salts and much more sugar than cows' milk.

If a considerable amount of fat be added to ass's milk, it is most like human milk of all the animal milks.

Milk.	Sp. grav.	Total solids.	Proteids.	Fats.	Carbohydrate.	Salts.	Water.
Human .	1027	12·60	2·29	3·78	6·21	0·31	87·41
Cows' . .	1032	12·83	3·55	3·69	4·88	0·71	87·41
Mares' . .	1035	9·21	1·99	1·21	5·67	0·35	90·78
Ass's . .	1026	10·40	2·22	1·64	5·99	0·51	89·64
Goats' . .	1032	14·30	4·29	4·78	4·46	0·76	85·71
Buffaloes' .	1032	18·60	6·10	7·47	4·15	0·87	81·41

Clotting of milk is the coagulation of the casein. Clots are of two kinds :—

(1) A firm clot, by the action of rennet, human gastric juice, etc.

(2) A loose clot, by the action of acids, etc.

If the lime salts of milk are chemically precipitated before use, then the clot formed by rennet or by gastric juice is of the second or loose type.

The lime salts can be precipitated (without injury to the milk) by adding :—

Sod. cit. gr. j to each fl. ℥j milk, and thus infants can digest the milk *without dilution.*

Condensed milk is milk evaporated from 1 gallon to to $2\frac{1}{4}$ pints and $1\frac{1}{4}$ lb. cane sugar added. It should be made from whole and not separated milk.

4. Butter.

On churning cream, the envelope of casein is broken up and the oil globules coalesce.

Butter consists of (*a*) glycerides of the following fatty acids :—

Butyric	6·1 %	Soluble and volatile.
Caproic Caprylic Capric	2·1 %	
Oleic	36·1 %	Insoluble.
Myristic Palmitic Stearic	49·4 %	

(*b*) Albumin (casein) (*c*) Carbohydrate (lactose)	2 %
(*d*) Water	12 %

Salt is generally added as a preservative 2 % in fresh and 4–6 % in salt butter.

Margarine contains no glycerides of the *soluble* fatty acids, but is a mixture of the palmitin and olein from beef and mutton fat, with a little buttermilk, anatto and water.

5. **Cheese.**

Butter we saw was prepared from the fat of cream. Cheese on the other hand is *prepared from the casein of milk.*

The casein is precipitated by the addition of rennet or an acid, and the curd so obtained is pressed and allowed to bacterially ripen.

The type of cheese varies as made from :—

(1) *Whole milk with added cream—e.g.* Stilton, Camembert, cream, etc.

(2) *Whole milk—e.g.* Cheddar, Gloucester, Gorgonzola (in which bread moulds are introduced during manufacture).

(3) *Skimmed milk—e.g.* Gruyère (cow), Parmesan (goat), Roquefort (ewe), Dutch (cow).

The other constituents of cheese, in addition to the casein, are :—*Fat,* which will vary according to the type of milk from which it is made ; *water,* and also a trace of *calcium salts* and *lactose.*

B. **Vegetable.**

1. **Wheat** (Triticum vulgare).

This grain consists of an outer envelope called *bran,* which is rich in salts and cellulose ; an *endosperm,* consisting chiefly of wheat starch ; and a central *germ* which is mostly composed of a proteid—glutin—and fat.

White meal flour is the ground-up product after the bran has been removed (carbohydrates 71 %, proteid 14, fat 2, mimerals 1, water 12).

Whole meal flour includes the bran (carbohydrates 76 %, proteid 10, fat 1, minerals 0·5, water 12·5).

Bread is a mixture of flour, water, yeast and salt; made into a dough, risen before a hot fire, and then baked in an oven.

Its coherency is due to the proteid glutin, and its sponginess to the CO_2 caused by the yeast fermentation.

The sponginess can also be secured without using yeast. This is done by forcing CO_2 into the dough under pressure (aërated bread) or by adding to the dough an acid and a carbonate (baking powder) which will evolve CO_2.

Bread is rich in proteid and starch, but poor in fat and salts—thus the common use of butter with bread.

2. **Oats** (Avena sativa).

Oatmeal is the most nutritious of all the cereals.

Its composition is proteid 15 %, carbohydrates and cellulose 67, fat 8, mineral 2, and water 8.

It thus has more proteid and much more fat than wheat flour.

The proteid is not glutin, but albumin, and therefore bread cannot be made from oat flour.

Grain which is hot rolled instead of ground gives the familiar product, "Quaker Oats."

3. **Barley** (Hordeum vulgare).

The composition much resembles that of wheat; but, as the proteid is not glutin, bread cannot be made from it.

Barley meal = whole grain when ground.
Scotch barley = grain husked and then ground.
Pearl barley = grain husked but not ground.
Patent barley = ground pearl barley.

4. **Rye** (Secale cereale).

Composition much resembles wheat, but is richer in sugar.

It contains glutin, and thus can be made into bread.

5. **Maize** (Indian corn).

This grain is poorer in cellulose, but richer in fat than is wheat.

It contains a little glutin, but not enough to make it into bread.

Hominy = maize mostly deprived of proteid.

Corn-flour, *Oswego* = most of the maize starches.

6. **Rice** (Oryza sativa). The staple food of a large section of the globe.

When unhusked it is called *paddy*.

It is rich in starch, but poor in proteid, fat, and salts.

7. **Peas** (Pisum sativum) and **Beans** (Broad bean = Faba vulgaris; French bean = Phaseolus multiflorus; Scarlet runner = Phaseolus vulgaris; Haricot bean = Phaseolus radiatus).

These leguminous seeds are rich in starch but deficient in fat and salts.

The proteid is a peculiar one, known as "legumin."

Combinations of sulphur and phosphorus occur in both peas and beans.

8. **Lentils** (Ervum lens).

These are rich in proteids and carbohydrates, and contain iron among the mineral constituents.

9. **Potatoes** (Solanum tuberosum).

The edible tubers of this plant contain 76 % of water and an excess of starch.

The juice is acid owing to the presence of free citric acid.

The proteid and fat are low.

They contain asparagin and potash salts.

10. **Turnips** (Brassica campestris).

The edible tubers contain a large amount of water and scarcely any proteids. The carbohydrate is known as pectose.

11. **Carrots** (Daucus carota).

The esculent root is well known.

As the plant will grow with less water than many others, it has proved of use in times of famine. It contains very little proteid, but much water and sugar.

12. **Green vegetables.**

Such as the *cabbage* (Brassica oleracea), the *lettuce* (Lactuca sativa), etc.

These are mainly composed of water and cellulose and are only valuable for the mineral salts which they contain.

13. **Prepared starches.**

(*a*) *Arrow-root.*

This is the starch extracted from the rhizome of Maranta arundinacea and other species of the genus Maranta.

It is expensive, and consequently frequently adulterated with the cheaper potato or tapioca starches, which can be detected by the microscope.

(*b*) *Tapioca.*

This is the powdered rhizome of the Cassava (Manihot utilissima), and is prepared by beating the moistened powder on hot plates.

NOTE.—Cassareep is the juice of a closely-allied species—the bitter Cassava—which has been concentrated by heat and flavoured with aromatics. It is then boiled with peppers and fish or meat, and forms the well-known West Indian "pepper pot."

(c) *Sago.*

This is the soft inner portion of the trunks of the Sago-palm (Metroxylon læve, East Indies, and Metroxylon rumphii, Malaya).

The pith is pounded in water till the starch separates. It is then washed, and becomes soft meal, after which it is shaken in a bag till it becomes granulated. 600–800 lbs. of sago are obtained from a single tree.

In the D.P.H. Examinations, samples of starch are frequently given under the microscope for identification. The following table will therefore be of use—

Name.	Shape.	Position of hilum.	Character of hilum.	Remarks.
Potato . .	Oyster	Small end	A dot	Large size. Striæ along grain
Arrowroot	Oyster	Large end	A dot	Large size. Striæ around grain
Pea . .	Oval	Longitudinal	Puckered	—
Bean	Oval	Longitudinal	Puckered	Hilum more puckered than pea
Wheat . .	Round	Central (if seen)	A dot	Grains both large and small
Barley . .	Round	Central	A dot	Grains in 3 sizes
Rye . . .	Round	Central	Stellate	Grains all sizes. Edges often split
Sago . .	Irregular busby	Irregular	Irregular, often cavernous	—
Lentil . .	Irregular busby	Irregular	Irregular	Larger grains than sago
Maize . .	5 or 6 facets	Central	Stellate	—
Rice . .	Faceted	Seldom seen	—	Very small grains. Agglomerates in angular masses
Oats . . .	Faceted	Seldom seen	—	Very small grains. Agglomerates in round masses

14. Nuts.

These contain a considerable amount of proteid and an excess of fat, and therefore differ from most fruits,

They are indigestible, however, owing to the amount of cellulose they contain.

15. Fruits.

These consist largely of *water*, *cellulose*, with a small quantity of *carbohydrate* (lævulose) and *salts* (chiefly malate, citrate, lactate, oxalate or tartrate of potassium or calcium).

The vegetable acids are replaced by sugar as the fruit ripens.

They are of anti-scorbutic value.

DIETARIES.

Varying quantities of food are required according to age, sex, occupation, health, season and climate. Less is required during infancy and old age, and by females, and in hot climates.

More is required during active exercise, in cold climates, during the procreative period, during lactation, etc.

The food is needed to build tissue, [illegible] waste, maintain heat and supply energy.

A man of average weight under moderate work excretes C. 300 grammes and N. 20 grammes in 24 hours.

His diet is calculated on this. To supply this will be necessary—

Standard Diet	**Proteid**	**125 grammes**	in 24 hours.
	Carbohydrate . .	**500 grammes**	
	Fat	**50 grammes**	
	Water	**2 litres**	

We can express this in terms of foodstuffs as follows:—

Meat	8 oz.
Potatoes	12 „
Bread	16 „

Butter	. . . .	2 oz.
Cheese	. . . .	1 ,,
Milk	. . . .	$\frac{1}{2}$ pint
Eggs	. . . .	2
Cornflour	. . . .	2 oz.
Oatmeal	. . . .	2 ,,

or by some similar combination.

Diet Scale Calculations.

1 oz. albumin	= N 70 grs.	C 212 grs.
1 ,, f[illegible]t	= N 70 ,,	C 336 ,,
1 ,, [illegible]bohydrates	= N 70 ,,	C 190 ,,

The b[illegible] proportion is N : 1 : : C : 15.

1 oz. uncooked beef	= N 12 grs.	C 60 grs.
1 ,, cooked beef	= N 19 ,,	C 110 ,,
1 ,, bread	= N 5 ,,	C 120 ,,
1 [illegible]tmeal	= N 8·8 ,,	C 168 ,,
1 [illegible]atoes	= N 1·4 ,,	C 45 ,,
[illegible]tter	= N 2 ,,	C 30 ,,
[illegible]lk	= N 2·8 ,,	C 30 ,,

Energ[illegible]om food.

The internal work of the body is estimated by De Chaumont at 2,800 ft. tons daily.

For external work 5 ft. tons' energy are necessary for 1 ft. ton work done.

If, therefore, we call an ordinary day's work ·300 ft. tons, then the number of ft. tons to be provided by the food will be 1,500 + 2,800 = 4,300 ft. tons.

Heat value of food.

The oxidation of food produces a certain quantity of heat.

We judge this by a standard called the *Food-Caloric*, i. e. the amount of heat required to raise 1 litre of water 1° C.

The heat value of—

1 gramme	Proteid	= 4·1	Calories
1 ,,	Carbohydrate	= 4·1	,,
1 ,,	Fat	= 9.3	,,

In problems, ounces and pounds of foodstuff must therefore be converted into grammes before m[illegible]lying by these figures—

(1 gramme = 1 oz. × 28·349)

The following number of food-calories [illegible] supplied for the following standard work—

	Calori[illegible]
1. Rest (clerk in office) .	[illegible]
2. Professional work (*e. g.* doctor)	[illegible]
3. Moderate muscular work .	[illegible]
4. Muscular work . .	[illegible]
5. Hard work (*e. g.* navvy)	[illegible]

De Chaumont's Principles of Diet.

1. No single principle, whether nitrogenous or non-nitrogenous, can support life except for a very short time.

2. Life can be supported by one nitrogenous and one non-nitrogenous principle for a long time, but not permanently.

3. For the best type of diet both fats and carbohydrates are needed in addition to nitrogen.

4. Mixed carbohydrates (*e. g.* starch *and* sugar) and mixed nitrogenous principles are advisable.

COOKING OF FOOD.

Advantages.	Disadvantages.
1. Food is sterilised. 2. Action of ptomaines is inhibited. 3. Flavour and aroma are improved. (Sugar changed to caramel.) 4. Putrefaction prevented. 5. Insoluble starch becomes soluble amylo-dextrin.	1. Loss of weight. 2. Proteid rendered less digestible (if over-cooked). 3. Irritating fatty acids are liberated. 4. Expense is increased.

METHODS.

I. Boiling.

(a) *Br[illegible]s.*—The meat is cut up small; soaked in cold wat[illegible] heat is applied slowly, and then finally boiled. Thus the albumin, extractions, etc., are removed before coagulated by the heat, while the meat still has some nutritio[illegible] value.

(b) *Sou[illegible]*[illegible]e procedure is the same, but the boiling is [illegible]onger, extracting more of the gelatin. The rema[illegible] has practically only fibrous tissue.

(c) *M[illegible]*[illegible]t is plunged suddenly into boiling water, [illegible]tes the surface albumin, and prevent[illegible]he subsequent escape of juice

After the first short boil the water is only allowed to simmer.

(NOTE.—The cooking point of meat is a temperature of 160° F., while B.P. is 212° F.)

(d) *Vegetables.*—The cellulose is softened and starch made soluble.

(e) *Milk.*—The serum albumin is coagulated, beginning at 65° C.

CO_2 is driven off by the high temperature, consequently the lime salts cannot hold all the casein in

solution, some of which rises to form the "skin"—also contributed to by some of the fat which cannot remain so much emulsified. Taste and colour are altered, and the casein is less easy of digestion.

"*Pasteurisation*" consists in keeping at 70° C. for half-an-hour, which kills pathogenic but not lactic acid bacteria.

II. Roasting.

More savoury but less digestible.

A thin crust of half-carbonised albumin forms on the outside, and prevents subsequent escape of the juices.

III. Stewing.

The idea is, not as in boiling, to retain the extracts in the meat, but to act both as a heat-giver and solvent. The best temperature is 160° F., and the process is best done in a water bath. If the meat has previously been cooked, the process is termed "hashing."

IV. Frying.

Cooking in boiling fat. There [illegible]aken idea that articles so cooked are penetra[illegible]. If the frying is properly done it is an exce[illegible]d, as the temperature is so high that the surfa[illegible] article is instantaneously carbonised and the juices re[illegible]ined.

The secret is to have the fat absolutely boiling *before* inserting the foodstuff. After cooking the article it should be put before the fire on a piece of blotting paper for a few minutes.

FOOD ACCESSORIES.

1. Tea.

The dried leaves of the *Camellia thea* from China, India, Ceylon and Japan. They are oval in shape, pointed, and with a serrated edge. The arrangement

of veins is characteristic; the large ones do not reach the edge of the leaf, but turn in towards the mid-rib.

The various names given to teas refer to the leaf. "Orange Pekoes" are the delicate top leaves. The lower, but still young leaves are "Suchong"; the older leaves, "Congou."

"Green," or China tea is dried over wood fires when fresh, and is often artificially coloured.

"Black" tea is first fermented in heaps for 12 hours, and afterwards dried slowly.

Adulterations consist of admixture of sloe and willow leaves, or old and exhausted tea leaves.

Tea is not a food. Its alkaloid—*thein*—is a nerve stimulant. Owing to the large amount of tannin it contains, excess will induce dyspepsia and constipation.

2. Coffee.

The seed of the *Caffea arabica,* from Arabia, Abyssinia, Ceylon and the West Indies.

It is roasted and ground before infusion, and in this process its alkaloid—*caffein*—is dissociated from the tannin, and the sugar is caramelised.

Adulterations consist of dates, beans, maize, or acorns.

The most frequent, however, is the dried and powdered root of the *Cichorium intybus* (chichory) often to the amount of 30 %.

Caffein is a useful stimulant of the nervous system.

3. Cocoa.

The roasted seed of the *Theobroma cacao,* chiefly from the West Indies.

Its alkaloid is *theobromin,* but it is not as stimulating as tea or coffee.

It possesses some nutritive value, and is a limited food, having excess of fat as well as starch and sugar.

Adulterations usually consist in the addition of sugar and starch.

4. Vinegar.

Dilute acetic acid contaminated with gum, sugar and vegetable matter.

Wine and malt vinegars are produced by oxidation of alcohol into aldehyde and then into acetic acid.

$$C_2H_5OH + O_2 = CH_3COOH + H_2O$$

Another method of preparation is by the destructive distillation of wood.

The percentage of acetic acid should vary between 3 and 6 %.

Adulteration is usually made by adding H_2SO_4 in excess of the legal 1 in 1000.

In small quantities vinegar is an aid to digestion, and also (like other acids) helps to maintain the alkalinity of the blood.

5. Aërated waters

consist of water or other liquids impregnated with CO_2 under pressure.

The danger consists in the use of a possibly contaminated water during their manufacture.

They slightly aid digestion, but in large quantities are depressing.

6. Beer.

Barley is soaked for 50 hours, then left to germinate for 2 weeks. It is then kiln-dried (*malt*), and the grain starch has been converted into sugar.

It is then crushed and put into water at 160° F., and the resulting liquor (*wort*) contains the grape sugar in solution.

Hops are added to the wort and the whole is boiled,

thus giving it bitterness and coagulating any dissolved albumins.

It is then cooled in shallow vessels for fermentation, and the yeast is added when the temperature is 60° F.

It ferments for 6 or 8 days, turning the sugar into alcohol and CO_2. This is beer.

Stout and *Porter* are beers coloured and flavoured with roasted malt.

The *alcohol in beer* varies from 1 to 10 %.

It has a higher nutritive value than other forms of alcohol.

It slightly aids digestion, but tends to fatten, and predisposes to gout and rheumatism.

Adulterations are: water, salt, alum, sugar or sulphate of iron.

7. Wine.

Fermented grape juice. Fruit juice at a moderate temperature itself ferments without addition of yeast. The sugar is converted into alcohol, ethers are formed which give it its bouquet, and tartaric acid is an essential constituent.

The colouring matter is derived from grape skins; with inferior wines, logwood, etc., may be added.

Natural wines, such as claret, Burgundy, etc., contain from 6 to 13 % of alcohol. *Fortified wines* (to which alcohol has been added) such as port, sherry, etc., contain 12 to 22 %.

The nutritive value of wine is small. It stimulates according to the amount of alcohol contained.

The lighter wines, containing much organic acid, are antiscorbutic.

The fortified wines predispose to gout.

Adulterations consist in adding spirit, colouring matter, "fining" (*i. e.* adding gelatin or isinglass to feed the yeast fungus till all the sugar has been converted), or "plastering" (*i. e.* adding gypsum), which

converts potassium tartrate into a more soluble potassium sulphate, clearing the wine; and also converts some of the tartaric into sulphuric acid.

8. **Brandy.**

The distillate of fermented grape juice. It contains 46 to 55 % of alcohol.

Adulterations are: water, cayenne pepper, burnt sugar, and acetic ether. Cheaper brandies are generally flavoured corn spirit.

9. **Whisky.**

Prepared from malted barley.

Raw grain whisky may be made from rye, potatoes, beetroot, etc.

It contains from 40 to 50 % alcohol.

10. **Rum.**

Spirit obtained by distillation of fermented sugar skimmings.

It is usually coloured with burnt sugar, and often flavoured with pine apple.

Alcohol—50 to 60 %.

11. **Gin.**

Made from malted barley, and flavoured with juniper berries, or oil of turpentine and orange peel.

Alcohol—49 to 60 %.

Adulterations: Water, sugar, alum, cayenne pepper.

FOOD-BORNE DISEASE.

1. Poisonous substances may be derived from food vessels; *e. g.* tinned foods.
2. The food itself may be poisonous; *e. g.* some shell-fish, toadstools, etc.
3. Putrefactive changes may give rise to poisonous ptomaines,

4. Animals may suffer from specific diseases, and convey them by flesh or milk ; *e.g.* tuberculosis, trichinosis, hydatids, etc.

5. Food may be infected by human contamination ; *e.g.* diphtheria, enteric fever, scarlet fever, cholera, etc.

MEAT INSPECTION.

Meat must be wholesome, genuine and of good quality.

I. Wholesomeness.

Meat may be unwholesome either from ante-mortem disease or post-mortem decomposition.

The chief diseases which render flesh unfit for human consumption are—

Cattle plague Pleuro-pneumonia Anthrax Sheep pox Tuberculosis Actinomycosis Joint-ill Foot-and-mouth disease Liver fluke Hoof-rot	Sheep and oxen.
Pleuro-pneumonia Typhoid Anthrax Foot-and-mouth disease Tuberculosis Quinsy Cysticerci Trichinæ	Pigs.
Glanders Farcy	Horses.

The Royal Commission on Tuberculosis, 1898, advised—

Entire carcase and all organs to be seized in case of—	1. Miliary tuberculosis of both lungs. 2. Tuberculous lesions on the pleura and peritoneum. 3. Tuberculous lesions in muscle. 4. Tuberculous lesions in any part of an emaciated carcase.
Only tuberculous parts to be seized in case of—	1. The lungs and thoracic lymphatics. 2. The liver. 3. The pharyngeal lymphatics. 4. A combination of the above, if small in extent.

The signs of commencing decomposition are—

1. Characteristic smell.
2. Greenish colour.
3. Soft consistence.

II. **Genuineness.**

For ox or heifer beef may be substituted bull meat, old cows or horse flesh.

For mutton may be substituted goats' meat.

Bull Beef.—The flesh is darker in colour ; the consistence is coarse and stringy. The fat is whiter and much less in quantity than in the ox. The bone is more massive.

If the carcase is seen whole distinguishing marks will be :—the large size of the erector muscle, the penis and pelvic bone ; and the absence of a plentiful supply of "cod" and "kidney" fat.

Old Cow.—The flesh is dark, coarse and stringy, and shows no marbling. The fat is scanty. The ribs are bleached.

The udder is soft, spongy, and brown in colour throughout.

Horse.—The flesh is much darker and coarser than that of the ox.

It has a sickly odour and a soapy feel. The fat is yellowish.

There are 18 pairs of ribs instead of 13 as in the ox.

Goats' flesh is darker than mutton, and has a goaty smell when heated.

III. **Quality.**

The characteristics of good meat are :—

1. The colour should be florid. (If pale = disease. If purple = death with blood in it, or acute fever.)

2. There should be a marbled appearance (from interposition of connective tissue and fat among the muscular bundles.)

3. It should not be very moist, and should have an acid reaction.

4. There should be very little smell, and that not disagreeable.

5. Consistence should be firm and elastic, and a knife pushed in will meet with uniform resistance.

6. It should not waste or shrink much on cooking.

7. It should not get wet on standing for a day or two.

8. If dried at 212° F. it should not lose more than 75 % of its weight.

9. There should be no sign of parasitic or specific disease.

10. The fat should not be too little, nor too yellow in colour, nor have a disagreeable smell.

11. The bone should be about 17 to 20 % of the weight.

At times, peculiarities of food may impart a disagreeable odour to the meat.

A cow may be slaughtered at twenty years of age, but the carcase would be very thin.

The best beef is from oxen of five or six years old.

Sheep are not milked, so that old ewes are not often patronised by the butcher.

CHAPTER IX

FOOD ANALYSIS

The following food-stuffs will be considered in this chapter :—milk, butter, cheese, bread, coffee, tea, tinned food, beer, wine, vinegar, pepper, and mustard.

An *exhaustive* analysis, even of these few substances, would be beyond the scope of this book, or the requirements of its readers. Analyses are alone given such as are daily required in a Health Officer's laboratory, and to medical men who have a knowledge of chemistry and the principles underlying that science, such analyses can be taught in a few weeks.

I. MILK.

The average *composition* of cow's milk is—

1.	Water	87·5 %
2.	Proteid	3·4 %
3.	Fat	3·6 %
4.	Lactose	4·7 %
5.	Salts	0·8 %

Milk samples should be examined as soon as possible, as they are useless when curdled. If only slightly curdled it may be possible to obtain a uniform mixture by shaking with a few drops of ammonia.

The reaction of pure milk is *amphoteric*, that is, it turns blue litmus red, and red litmus blue. The B. acidi lactici and other bacteria quickly turn it acid. The milk tastes sour with 0·4 % of lactic acid, and curdles when the acidity reaches 0·6 %.

The proteids are chiefly composed of casein, with about 0·5 % of lact-albumin and traces of globulin.

In our practical examination the following points need alone be determined :—

(*a*) Specific Gravity (1029 to 1034) at 15·5° C.
(*b*) Total Solids (12·5 %).
(*c*) Ash (0·75 %).
(*d*) Fat (3·5 %).
(*e*) Presence of preservatives. (Borax. Formaldehyde. Salicylic Acid.

(*a*) **Specific Gravity.**

The sample should be brought to 15·5°C. by standing in water.

It is then shaken to mix the cream and the specific gravity taken by a hydrometer.

The specific gravity of a pure cow's milk will vary between 1026·5 and 1036·5.

(*b*) **Total Solids.**

Take a platinum dish and carefully weigh it. Note weight (x).

Without removing it from the scale-pan of the balance, put into it by pipette 5 c.c. of the sample after well shaking.

Weigh again carefully and note down the weight of dish and milk (y).

Dry for three hours on a water bath ; then wipe the dish while still hot, transfer to desiccator, and when cool weigh again (z).

NOTE.—It is generally recommended after putting on the water bath, to dry in a water oven for an hour or two. Better results have, however, been obtained by Leach (in a series of over 30,000 examinations) by using the desiccator as above.

Then $(z-x)$ = total solids in $(y-z)$ grammes of the sample. How much will be found in 100 grammes of the sample ?

NOTE.—They should average 12·5 %, which is composed of :—

Total Solids	Fat	3·5 %		
	Solids-not-fat	9 %	Casein, etc.	3·4
			Lactose	4·7
			Mineral	0·9

(*c*) **Ash.**

The residue after the above determination is cautiously heated over a Bunsen burner at a dull red heat to a perfectly white ash. If heated too much there will be a loss of sodium chloride.

The dish is now carefully weighed (x').

Then $(x' - x)$ = ash in $(y - z)$ grms. of sample.

Note.—The ash should be about 0·75 %.
Ash much less than this may point to watering.
A constant figure in normal milks is—
Ash : solids-not-fat : : 8·3 : 100.

The dish and ash should be carefully kept for later boric acid determination.

(*d*) **Fat.**

There are three chief means of determining the fat in milk.

(1) *Adams Method.*

This is the official method of the Society of Public Analysts, and is the most accurate of all.

The *rationale* is the extraction of fat by *dry* ether which has no solvent action on milk sugar, and thus only removes the fat.

The *modus operandi* is as follows—

Strips of fat-free filter-paper $2\frac{1}{2}$ in. wide and 22 in. long are required.

On to one of these after weighing (z) 5 c.c. of the sample are spotted out through the pipette and then re-weighed (z').

The paper is then allowed to dry in air, and finally for a few minutes in a water oven.

It is then rolled up and put into the tube of a "*Soxhlet Extractor.*" This apparatus consists of a flask, a Soxhlet tube and a condenser. The Soxhlet tube is wide at the top (where the Adams paper is inserted) and smaller below. It has two glass tube attachments.

Through one of these attachments the vapour of the distilled ether passes upwards into the condenser, where it condenses and drops back into the wide part of the Soxhlet tube.

As the wide part of the tube is not connected with the narrow part, the liquid condensed will continue to rise in the wide part until it reaches the top of the small attached siphon, when it all siphons back into the distilling flask.

In this way the process goes on automatically without attention, the ether at each siphoning extracting more of the fat from the paper.

In actual practice, the spotted paper is put in the Soxhlet tube. Enough dry ether to fill the tube $1\frac{1}{2}$ times is put into the distilling flask, which was previously carefully weighed (x).

Then the tube is fitted above the flask, and the condenser above the tube.

The condenser is connected up with the water supply and set going.

Underneath the distilling flask is placed a water bath as a source of heat.

The degree of ebullition must be regulated to give a quiet and steady action, and the process should be continued till it has siphoned over 12 times.

The flask is then detached and put on the water bath until the ether has evaporated. It is then dried in a water oven and cooled in a dessicator, after which it is weighed (y).

Then $(y-x)$ grammes = fat in $(z'-z)$ grammes of sample

(2) *Leffmann-Beam Method.*

This is a fairly accurate, easy, and most generally adopted method.

The *rationale* is the destruction of casein and liberation of the fat by means of treatment with an acid. Also the use of amyl alcohol (which is soluble in the acid liquid) to assist in the collection of the fat globules.

The *modus operandi* is as follows—

Small flat-bottomed Leffmann-Beam flasks are required. These hold about 40 c.c. graduated on the long neck into 80 divisions, 10 of which correspond to 1 % of fat.

The sample is well shaken, and 15 c.c. are pipetted into the flask. To this is added 3 c.c. of a mixture of equal parts of HCl and amyl alcohol (fusel oil).

The flask is well shaken and then 9 c.c. of H_2SO_4 (95 %) is added drop by drop with agitation.

A mixture of H_2SO_4 and water is now slowly added to bring the liquid up to the zero mark.

The flask is now centrifugalised, which frees the lighter fat and sends it to the top where the reading from the top to the bottom of the fat column can be read off against the graduations in the neck.

Then 10 divisions = 1 % fat in 15 c.c. sample

(3) *Werner-Schmidt Method.*

A special tube is used, graduated up to 50 c.c.

The sample is shaken and then 10 c.c. are pipetted into the tube.

HCl is added roughly to the 20 c.c. mark.

The mixture is boiled for 2 minutes, when it turns brown.

It is then cooled by immersion in water.

It is made up to the 50 c.c. mark with ether.

The tube is then corked, and the mixture shaken for ½ minute.

It is allowed to stand for 5 minutes.

Then 20 c.c. of the supernatant ether are pipetted into a tarred beaker, the ether evaporated on a water bath, dried in an air oven, cooled in a desiccator, and weighed.

This difference between this weight and the weight of the beaker will of course give the weight of the fat in 20 c.c. of ether. The number of c.c. of ether still left in the tube is now read off, and a calculation will give the fat present in *all* the ether, which will of course equal the fat present in 10 c.c. of milk.

(*e*) **Preservatives in Milk.**

(1) *Carbonate or boracic acid.*

The ash remaining in the platinum dish after incineration of the total solids will now be required.

One or two drops of dilute HCl are added to the ash by pipette.

Effervescence = added carbonate.

A few c.c. of water are now added from the wash-bottle.

The dish is gently rotated to hasten solution of the ash.

A strip of *turmeric paper* is then soaked in the dish for a few minutes and allowed to dry.

If the paper when dry is deep cherry-red and turns dark olive when treated with dilute alkali = boric acid present.

(2) *Formaldehyde.*

The following stock solution is used as a *re-agent*—

$$\begin{cases}\text{Ferric chloride } (10\ \%)\ 2\text{ c.c.}\\ \text{Commercial HCl } 1000\text{ c.c.}\end{cases}$$

10 c.c. of this re-agent is added to 10 c.c. of the milk in a porcelain dish.

It is heated slowly over a free flame nearly to boiling, gently rotating the while.

If there is no formaldehyde the liquid turns brown slowly.

If formaldehyde is present (down to 1 part in 250,000) *it will be indicated by a violet coloration.*

(3) *Salicylic Acid.*

This is now but rarely used as a milk preservative.

The following stock solution is used as a *re-agent*—

Metallic Hg 1 part by weight, dissolved in HNO_3 (S.G. 1·42) 2 parts by weight.
To this is added an equal volume of water.

To 50 c.c. of the milk is added 1 c.c. of the above stock re-agent. It is then shaken and filtered.

The filtrate (which should be clear) is shaken with ether in a separating funnel.

The ether is drawn off and evaporated, and a drop of Fe_2Cl_6 applied.

A violet colour = salicylic acid.

II. **BUTTER**.

The average composition of butter is—

Butter-fat	85 %
Water	12 %
Salt (up to)	10 %
Casein	0·3 to 4·0 %

The butter-fat consists of the glycerides of butyric (6·1 %), caproic, caprylic, and capric (2·1 %) acids, which are all soluble; also of oleic (36·1 %), myristic, palmitic and stearic (49·4 %), acids, which are insoluble.

Margarine and such compounds differ from butter in having practically no "soluble" fatty acids.

For ordinary purposes, the determination of the fat and of the preservatives are all that is necessary.

(1) **Fat.**

(*a*) *Reichert-Meissl Method.*

The *modus operandi* is as follows—

Five grammes of liquid fat are weighed into a flask (300 c.c.).

Ten c.c. of 95 % alcohol are added, and 2 c.c. of NaOH solution (100 in 100 c.c.)

The flask is then attached to a reflux condenser, heated over a water bath and the contents allowed to boil briskly for 20 minutes.

The condenser is now removed and the alcohol boiled off.

To the flask are now added 100 c.c. of hot water, and the whole shaken until the soap is dissolved.

After cooling 5 c.c. of dilute H_2SO_4 (200 parts to the litre) are added, with a little pumice or small glass rods.

The flask is now attached to an ordinary condenser and heated over a Bunsen till 160 c.c. have distilled over.

The distillate is filtered and titrated with $\frac{N}{10}$ soda, using phenolphthalein as an indicator.

The number of c.c. + $\frac{1}{10}$, required to neutralise the acidity of the distillate from 5 grammes of the fat is known as the "*Reichert-Meissl number.*"

Genuine butter fat requires from 24 *to* 32 *c.c. Margarine or vegetable oils only require* 0·2 *to* 1·0 *c.c.*

The principle of the above process is a preliminary saponification of the fats.

During a subsequent distillation, the *volatile* fatty acids will alone distil over, and can thus be estimated.

(b) *Valenta Acetic Acid Method.*

Three c.c. of melted butter and 3 c.c. of acetic acid (99 %) are run into a graduated test tube.

The mixture is warmed till clear, the temperature at which it clears being noted by a thermometer. It is then allowed to cool, and the temperature at which it becomes cloudy is noted. The mean of these two readings is recorded.

In the case of good butter the figure is 40° C. or below.

In the case of margarine, it will be above 75° C.

(2) **Preservatives.**

These will be either an excess of salt, or boric or salicylic acids. These may be detected as advised under the head of "Milk."

III. CHEESE.

The composition of cheese, as explained in the last chapter, will vary as whether it is made from cream, cream and milk, whole milk, or skimmed milk.

The average composition is:

Water	30 %
Ash	3 to 6 %
Fat	20 to 45 %
Casein	20 to 30 %

Dutch cheese has the least fat.

Stilton has most fat and least water.

Camenbert has most water.

For analysis of cheese all we need estimate is:—

1. Water.
2. Ash.
3. Fat.

1. *Water.*

Five grammes of the cheese are weighed in a platinum dish after being cut in thin slices.

They are then dried in an air oven at 105° C. till constant in weight. The loss of weight will give the water in 5 grammes.

The dry sample can then be used for

2. *Ash.*

It should be ignited at as low a temperature as possible, to a white ash, which is then weighed.

3. *Fat.*

The best method is the *Ether Extraction Process.*

Fifty grammes of sample are ground up in a mortar with an equal amount of pure sand. The mixture is placed in a tall stoppered cylinder and extracted with 100 c.c. of ether. The process is repeated three more times using the same amount of ether. The 400 c.c. of ether is well shaken, and $\frac{1}{4}$ of it is evaporated in a bared dish, which is afterwards weighed. This amount of fat $\times$ 4 = the fat in 50 grammes of sample.

Adulteration usually consists in either using skimmed milk which will give a low "fat" figure; or by substituting foreign fat for milk fat, which can only be detected by estimating the volatile fatty acids as in the case of butter (Reichert Method).

IV. BREAD.

The following is the average composition of bread—

Water	35·8 %
Carbohydrates	51·5 %
Proteid	7·0 %
Sugar	4·0 %
Fat	0·4 %
Cellulose	0·3 %
Ash	1·0 to 1·5 %

Analysis is directed only to the following points:—

1. Water.
2. Acidity.
3. Presence of added alum.

1. *Water.*

Water should never exceed 40 %.

A sample of known weight is then dried to constant weight at 105° C. The loss of weight = water in the amount of sample taken.

2. *Acidity.*

Ten grammes of the crumb are rubbed up in a mortar with water, and then titrated with $\frac{N}{10}$ alkali, using phenolphthalein as an indicator.

To neutralise the acidity of this amount of normal bread, an average of 2 c.c. is required (corresponding to 0·72 grammes of lactic acid per loaf of 400 gramme weight).

The maximum permissible acidity is 10 c.c. (= 3·87 grammes lactic acid per loaf of 400 grammes).

3. *Presence of added alum.—Logwood Test.*

Re-agents required—

(*a*) 5 grammes logwood digested in 100 c.c. alcohol.
(*b*) Saturated solution of Amm. Carbonate.

Modus operandi—

Five c.c. each of logwood and carbonate solutions are mixed and made up to 100 c.c. with water.

This is then poured over a lump of crumb (about 10 grammes).

After 5 minutes the fluid excess is drained off and the bread dried in the dish, at 100° C.

If alum is present, the sample will show a violet or blue tint, more obvious on drying.

If free from alum, the preliminary brownish tint fades to a buff colour.

V. COFFEE.

Coffee is the seed of the *Caffea arabica* (Nat. Ord. Cinchonaceæ).

Its usual data are—

Water	6 %
Total Ash	4 %
Fat	10 %
Caffein	1·2 %
Sp. gravity of decoction (10 %) .	1009·5

Its most frequent adulterant is chicory—the wild endive—*Cichorium intybus* (Nat. Ord. Compositæ).

The chicory data are—

Water	10·5 %
Total Ash	5·4 %
Fat	1·8 %
Caffein	nil
Sp. gravity of decoction (10 %) .	1024·5

A full analysis of coffee is seldom required.

The relative proportions of coffee and chicory are all that will have to be determined.

Modus operandi—

Put 20 grammes in 200 c.c. water.
Bring it to the boil.
Strain and filter.
Cool to 15·5° C.
Take specific gravity with a Westphale balance.

Determination.

Now—

Sp. grav. of coffee decoction = 1009·5
„ „ chicory „ = 1024·5

Let Sp. grav. of sample = x

Let Difference between x and 1009·5 = y
„ „ x and 1024·5 = z

Then $(y + z) : y :: 100 : \%$ chicory

and $(y + z) : z :: 100 : \%$ coffee

Microscopical Examination.

The sample is extracted with ether to remove fat, and then extracted with spirit and water to remove colouring matter.

The residue is washed, boiled for a minute with a 2 % solution of NaOH, washed again and mounted in glycerine and water on a glass slip.

Coffee grains contain a structure of bars like a wooden paling.

Chicory shows hollow spiral ducts never seen in coffee.

VI. TEA.

The leaf of the *Thea sinensis.*

Tea used to be adulterated with adventitious leaf, such as the willow, sloe, hawthorn, etc., but it is now rare.

The *average composition* is—

Water	6 %
Caffein	1·8 to 3·5 %
Tannin	15 %
Volatile Oil	0·5 %

Gum, dextrine, wax, etc., traces.

A complete analysis is seldom necessary.

The following points may be determined :—

1. Amount of theine.
2. Total ash.
3. Soluble ash.
4. Alkalinity.

1. *Amount of theine.*

Boil 6 grammes of finely powdered tea in 500 c.c. of water with a reflux condenser, for 5 or 6 hours.

Filter, and make filtrate up to 600 c.c.

Raise to boiling point and add 4 granules of powdered lead acetate and boil for a few minutes.

Allow to settle and filter 500 c.c.

Concentrate this to 50 c.c.

Extract 4 or 5 times with chloroform.

Evaporate the chloroform in a tared flask.

Weight = total theine in 6 grammes.

2. *Total Ash.*

Five grammes are dried in a tared platinum dish and then ignited at the lowest temperature, to give a grey, not a green ash.

The weight will give the total ash in 5 grammes, and should average 6·0 %.

The ash should now be extracted with hot water till the filtrate is no longer alkaline, to give the—

3. *Soluble Ash.*

The filter paper is now ashed and weighed. (Keep the filtrate for [4]).

The soluble ash is estimated by deducting the weight of the insoluble ash from the total ash.

4. *Alkalinity.*

The filtrate of the above process is now titrated

with $\frac{N}{10}$ HCl, using methyl orange as an indicator. (1 c.c. $\frac{N}{10}$ acid = 0·0047 K_2O.)

Note.—Exhausted leaves are detected by low theine, low soluble ash and low alkalinity.

VII. TINNED FOOD.

Food tinned, if a vacuum be secured, will keep good for a long time.

Decomposition of its contents will give rise to gas formation and a bulging of the tin.

Crafty purveyors will let the gas out by a small hole, re-boil and seal up.

Tinned food may prove dangerous in one of three ways—

1. Decomposition of contents.
2. Absorption of tin, lead, or zinc, by the contents.
3. Addition of copper or other colouring matter to tinned peas, etc.

1. *Examination for ptomaines.*
   - *a.* Cut up contents.
   - *b.* Acidify with acetic acid.
   - *c.* Digest with water for an hour.
   - *d.* Filter and evaporate filtrate to syrup.
   - *e.* Mix with 3 times its vol. of alcohol.
   - *f.* Distil again to thin syrup and cool.
   - *g.* Digest with water (fats and resins separate).
   - *h.* Filter through wetted paper.
   - *i.* Add lead acetate as long as precipitate falls (decolorises).
   - *j.* Pass H_2S (throws down lead).
   - *k.* Filter and evaporate to an extract.
   - *l.* Treat with 50 c.c. alcohol (mucus and dextrins precipitated).
   - *m.* Filter and evaporate alcohol.
   - *n.* Take up residue with 50 c.c. water and filter.

A small portion of the filtrate is now concentrated.

Add 1 drop H_2SO_4 conc.
1 drop $K_3Fe_2Cy_6$
1 drop Fe_2Cl_6.

Blue precipitate = Ptomaine.

2. *Examination for metals.*

Digest contents with HCl solution for an hour.
Filter and evaporate filtrate to syrup.
Mix with three times its vol. of alcohol.
Distil again to thin syrup.
Digest with water (to separate fats, etc.) and filter through wetted paper.
The filtrate can now be tested by the usual tables for metals.

VIII. BEER

is a fermented saccharine infusion, prepared from malt and flavoured with an infusion of hops.

In analysis we determine the following:—

Alcohol.
Sodium chloride.
Fixed acid (as lactic and succinic).
Volatile acid (as acetic).

1. *Alcohol.*

Take 100 c.c. of the sample.
Make alkaline with NaOH.
Add a little tannin to prevent frothing.
Distil over 70 c.c.
Cool to 15·5° C.
Make up to 100 c.c. with water.
Take the specific gravity.
The amount of alcohol can now be found from the tables.

2. *Sodium chloride.*

Five c.c. are taken and evaporated and ashed.

The ash is exhausted with water, and the solution is titrated with $\frac{N}{10}$ $AgNO_3$ (1 c.c. = 0·00585 Na Cl), using neutral potassium chromate as an indicator.

(NOTE.—A standard of 50 grs. per gallon is permissible.)

3. *Total acid.*

Twenty c.c. of the sample is diluted to 100 c.c. and titrated with $\frac{N}{10}$ NaOH, using litmus as an indicator.

The number of c.c. alkali is noted.

4. *Fixed acid.*

Twenty c.c. is diluted to 100 c.c. and evaporated to 50 c.c. This gets rid of the volatile acid.

The solution is then again diluted to make 100 c.c. and titrated with $\frac{N}{10}$ NaOH, using litmus as an indicator.

The number of c.c. used × 0·009 = fixed acid as lactic.

The number of c.c. used, deducted from the number of c.c. used for the determination of total acids, and multiplied by 0·006 will give the volatile acid as acetic.

IX. WINE.

The analysis is usually confined to estimating the amount of alcohol and the acidity.

The *alcohol* can be estimated by direct distillation as described for beer.

The *fixed acid* is determined by diluting, say 20 c.c.

with 100 c.c. water, evaporating to 50 c.c. and making up to 100.

Then titrate with $\frac{N}{10}$ NaOH, using phenolphthalein as an indicator. The number of c.c. $\times$ 0·0075 = fixed acid as tartaric.

The *volatile acid* is determined by diluting 20 c.c. of the sample to 100 c.c. and titrating with $\frac{N}{10}$ NaOH. Deduct from this number of c.c. alkali used (total acidity) the number used in the fixed acid determination. This will give if multiplied by 0·006 the volatile acid as acetic.

X. VINEGAR.

This is the product of alcoholic and acetous fermentation of a vegetable infusion.

Malt is soaked in hot water ; yeast is added. The whole is pumped over twigs, and the C_2H_5OH is thus turned into CH_3COOH.

The pleasant taste is due to acetic ether and aldehyde.

The following are the average data—

Sp. gr. at 15·5°C. . . .	1019
Acetic acid	5·5 %
Extract	2·5 %
P as P_2O_5	0·08 %
N	0·08 %
Ash	0·5 %

Analysis is directed to the determination of the acetic acid, the nitrogen, and the P_2O_5.

1. *Acetic acid.*

Ten c.c. of the sample are diluted to 100 c.c. and

titrated with $\frac{N}{10}$NaOH, using phenolphthalein as an indicator.

The number c.c. used $\times$ 0·006 $\times$ 10 = percentage CH_3COOH.

2. *Nitrogen.*

Twenty-five c.c. of the sample are evaporated in a Kjeldhal's flask.

Add 20 c.c. H_2SO_4, conc. and 5 grammes K_2SO_4.

Heat till yellow.

(The N is all now in form of $(NH_4)_2\ SO_4$).

Add 200 c.c., water.

Put in a distilling flask. Add 70 c.c. NaOH (50 %) and 200 c.c. more water.

Distil 250 c.c. into $\frac{N}{10}H_2SO_4$. The ammonia coming over will neutralise a certain amount of this acid.

How much acid is left unneutralised is determined by titrating it with $\frac{N}{10}$ NaOH.

Number c.c. NaOH $\times$ 0·0014 = N.

3. *P_2O_5.*

Twenty-five c.c. are evaporated and ashed.

Add a little HNO_3.

Dilute and filter.

Add 20 c.c. NH_3 fort.

Then HNO_3 till precipitate formed is dissolved.

Dilute NH_3 now again added till faint opalescence is formed.

Add 2·5 c.c. HNO_3 conc.

Warm the solution to 70° C.

Run in 20 c.c. amm. molybdate sol. (10 %) with constant stirring.

Cool. Filter. Wash precipitate with hot water, then alcohol, then ether.

Dry filter paper.

Remove precipitate and weigh.

Weight × 0·0373 = P as P_2O_5.

XI. PEPPER.

The dried unripe fruit of *Piper nigrum*.

The composition is—

	Black Pepper.	*White Pepper.*
Volatile oil . . .	2 %	2 %
Glucoside (piperin) .	2 to 3 %	2 to 3 %
Cellulose . . .	8 to 11 %	4 %
Starch	35 %	42 %
Acrid resin . . .	4 %	4 %

The white variety is the ground-up seed after being husked. It therefore contains much less cellulose.

The *adulterants* of pepper are maize, nutshells, gypsum, sand, clay, olive stones, and ground-rice.

When ashed, black pepper gives 5 %, and white pepper 3 %.

Ground olive stones (poivrette) give less ash, and considerably less residue after boiling in acid than in alkali.

XII. MUSTARD.

The composition is—

Water	5 %
Volatile oil (ol. sinapis) . .	5 %
Fixed oil	35 %
Fibre, Albuminoids	variable
Ash	5 %

Mustard differs from pepper in having *no* starch.

The adulterants (except poivrette) are much the same as in pepper.

CHAPTER X

DISINFECTION AND DISINFECTANTS

PHYSICAL AGENTS.

(a) *Sunlight* is an active germicide, but only acts on directly exposed surfaces, and is not of practical application.

(b) *Fire.*—Garbage, refuse, and infected articles of small value should be subjected to this perfect disinfection.

(c) *Dry heat.*—A temperature of 150° C. for 1 hour will destroy all bacteriaceæ and spores, but many fabrics are injured by 110° C. or over.

(d) *Moist heat* is quick and reliable.

If streaming, will kill all spores in ½ hour.

If super-heated by pressure, less time will be required.

This method cannot be used for leather, rubber, skins or fur.

GASEOUS AGENTS.

(a) *Formaldehyde gas* (CHOH).

This is one of the best disinfectants, for it is non-poisonous, is a good germicide, a true deodorant, does not damage materials, and does not coagulate albumin. It has therefore a much wider range of usefulness than carbolic or perchloride.

For use we either—

1. Boil a formalin solution.
2. Spray with formalin.
3. Heat paraform.
4. Mix formalin with an alum solution and allow to drip on quicklime, which liberates the gas.

(b) SO_2.

If this gas can be introduced at sufficient pressure it is good, for it is cheap, and can destroy vermin as well as bacteriaceæ.

If moist, however, it damages fabrics, and in no case will kill spores.

It is used either—

1. By burning in an open pot, which of course gives no pressure.
2. By spraying liquid SO_2, which is expensive.
3. By burning in a furnace which can pump out under pressure (such as the Clayton machine).

(Note.—1 lb. of S. gives 1·15 % SO_2 in 1000 cub. ft. of space. At least 5 % should be present to kill bacteriaceæ.

LIQUID AGENTS.

(a) *Carbolic acid* (C_6H_5OH).

Derived from coal-tar oil. A 5 % solution is commonly employed—7 % represents saturation.

It does not always kill spores, but otherwise has a fairly wide range of application and does not coagulate albumin nor damage fabrics.

(b) *Tricresol.*—A mixture of the coal-tar cresols—the meta- (liquid) with the ortho- and para- (solid) cresols.

Since it is three times as powerful as carbolic, a 1 % solution can be used.

(*c*) *Lysol.*—This is a valuable germicide of equal power to tri-cresol.

It is composed of 50 % cresols with soft soap basis, and mixes with water in all proportions.

(*d*) *Jeyes' Fluid.*—This also consists of cresols (10 %) to which a little carbolic is added, and the whole held in solution with soap.

It is fairly cheap, much superior to carbolic, and forms a good white emulsion with water.

(*e*) *Izal.*—A 40 % emulsion of izal oil (one of the coal-tar oils intermediate between the benzene and paraffin series).

It is of stronger power than carbolic, and has the great advantage of mixing well with sea-water as well as fresh.

(*f*) *Corrosive Sublimate* $HgCl_2$.—This salt is soluble in 3 parts of hot and 16 parts of cold water, but is best kept in a saturated (25 %) alcoholic solution with a little ammonium chloride.

Sea-water can be used for making up the solutions if so required.

Its range of practical usefulness is limited, for it is poisonous; it is decomposed by metals; and it forms inert and insoluble substances with proteid matter.

(*g*) *Formalin*, HCOH Aq. (40 %).—A 4 % solution is equal in value to 1 in 1000 $HgCl_2$ and superior to 5 % carbolic. It is moreover a true deodorant, does not attack metals and does not form inert substances with albumen.

(*h*) *Lime Solutions—Whitewash* $Ca(OH)_2$ Aq. is useful for disinfecting walls, and should be freely applied to stables, outhouses, etc.

Chloride of lime CaClOCl (bleaching-powder). Ranks with unslaked lime as a germicide, but can only be used for floors, woodwork, etc., as it destroys and bleaches fabrics.

(*i*) *Potassium Permanganate* ($KMnO_4$).—Purple crystals, soluble in 2 parts of hot and 16 parts of cold water.

It is a germicide of considerable power, but cannot be used in the presence of much organic matter, as it readily gives up its O to it.

Contaminated tanks and wells may be thus disinfected, adding enough $KMnO_4$ to give the water a tinge of colour.

The safer plan, however, is to empty out the tanks and steam them.

Stains can be removed by acids.

Application of Disinfectants.

Air.—One of the gaseous agents should be employed.

Bandages.—Boiling, steaming, or dry heat.

Bed Linen.—Boiling, steaming, or immersion. (Wool will shrink in boiling.) 5 per cent. formalin for two hours, then remove and wash.

Beds.—Hot carbolic.

Bedding.—Pressure steam.

Brushes.—If no glued backs, boil or steam; if glued backs, cleanse in soap, wash, and immerse in 5 per cent. formalin.

Books.—These cannot be disinfected on shelves. The exposed surface, however, is the only part probably infected if the book has not been opened.

They should be stood open on wire trays in a closed chamber and exposed for twelve hours to formalin vapour at a temperature of 80° C.

The binding, illustrations, and print are not injured.

Cadavers.—The corpse at death should be wrapped in a sheet saturated with strong disinfectant if death has been due to infectious diseases.

If subsequent cremation is not feasible, the body should be surrounded with quicklime and the coffin tightly sealed.

Carriages.—These may be run into a closed shed and subjected to the vapour of formalin or SO_2, which will give surface disinfection.

If the vehicle has been used for infectious disease, all loose upholstery should be removed and separately dealt with; the rest of the interior being saturated with a strong solution of formalin, the woodwork scrubbed with lysol, and the whole then aired in the sun.

Clothing.—This may be exposed to steam, dry heat, gases, or solutions.

Leather, hide, skins, fur, or woollen goods should not be boiled or steamed.

Formalin gas admitted to a chamber with a partial vacuum is an admirable means of treating clothing.

Steam is excellent for many articles, especially if kept dry by high surrounding temperatures. SO_2 is of little use, owing to lack of penetration.

Colours.—Articles with colours should not be subjected to steam, boiling water, SO_2, or chlorine. Solutions are also liable to make them run. They should be treated with formaldehyde gas.

Carpets should be first exposed to disinfecting gas, such as formalin.

Stains of excreta or discharges should be scrubbed with hot solution of lysol. The carpet can then be steamed and finally aired in the sun.

Curtains.—Steam.

Excreta.—Cover from flies, etc. Mix thoroughly with milk of lime (1 of quicklime to 8 of water).

Or formalin can be incorporated, acting both as germicide and deodorant. When possible, incinerate.

Food.—In districts of cholera, typhoid, or dysentery, all salads, celery, tomatoes, fruit, etc., should be immersed for half an hour in 3 per cent. tartaric acid, and afterwards washed in boiled water. Surface disinfection of fruits and vegetables may also be effected by immersion in 5 per cent. solution of formalin, which does not harm them, and is non-poisonous.

Floors.—Soak in 5 per cent. carbolic. Then scrub with soap and hot water.

Furniture.—If this has not come in contact with patient or infectious material, gaseous disinfection of the room with formaldehyde will be sufficient.

If contamination has occurred, any upholstery should be removed and burned; and the woodwork washed with strong formalin.

Glass.—This, as well as china, porcelain, etc., should be boiled.

Hands.—A nail-brush should be used with hot water and 5 per cent. of lysol. This is sufficient for any or every circumstance if carefully carried out.

Hats.—Formaldehyde gas.

Houses.—Treat each room separately with formaldehyde fumigations. Subsequently, wash throughout with hot water and soap, air thoroughly, re-paper, paint, and whitewash throughout.

Instruments (Schimmelbush's method).—Boil for fifteen minutes in a 1 per cent. solution of sodium bicarbonate. It does not rust or affect the cutting edge.

Leather.—This, together with skins, fur, etc., are ruined by boiling, steaming, or immersing in strong solutions. Dry formaldehyde gas is probably the best method.

Mails.—Letters probably have little connection with the spread of plague, cholera, typhoid, or tuberculosis.

They are a *grave source of danger in smallpox* cases, although exempted from sanitary treatment by the various sanitary conventions. They also probably carry measles and scarlet fever.

The best disinfection is to clip a tiny corner of the envelope, drop in two or three drops of formalin. Spray formalin inside the bag, and a fine spray between the letters as they are re-inserted. Then tightly close the bag. By the time it reaches its destination it should be quite safe.

Milk.—Either boil or pasteurise. The latter method is carried out by heating to 75° C. (180° F.) for half an

hour, then keep on ice. This does not coagulate the casein.

Money.—Coins should be boiled for half an hour.

Paper money should be sprinkled with formalin and shut in a warm box for six hours.

Paintings.—Uninjured by formaldehyde, which should always be used.

Rags.—Burn, or expose to steam under pressure.

Rubber.—Injured by dry heat. Immerse in formalin solution.

Silk.—Injured by steam. Use formaldehyde gas.

Sputum.—Expectorate (in infectious diseases, such as phthisis, diphtheria, etc.) in covered cuspidors containing 2 per cent. lysol.

The sputum should subsequently be burned, as also soiled handkerchiefs, etc.

Stables.—Remove loose articles for treatment separately. Hay and straw should be removed and burnt. Spray throughout with strong formalin, and subsequently whitewash.

Tableware.—Boil.

Tents.—Spread in sun and soak in formalin.

Urine.—Add 3 to 5 per cent. of formalin.

Vessels.—Shipboard disinfection will vary with the disease at stake.

> *If for plague*, disinfect all holds, cabins, stores, etc., with SO_2 gas under pressure for some hours, keep shut up for twenty-four hours to destroy vermin, etc. Then open, wash with Jeyes' fluid, burn rats, paint, and whitewash throughout.
>
> *If for smallpox*, much the same procedure, but chief care directed to the actual domicile of the patient.
>
> *If for cholera*, the same procedure throughout the ship, though less gas will be needed. The bilges should also be pumped out and Jeyes' fluid inserted.

The water tanks should be emptied, and steamed from the ship's boilers. The stores also should be overhauled, and any vegetables or suspicious fruits, etc., condemned.

Care should, in all cases, be taken to inquire into the nature of the cargo and ballast, which can be dealt with as circumstances may demand.

If dry, SO_2 will practically damage no cargo.

Cabins should be tightly sealed and treated with formaldehyde.

Walls.—Scrub with hot lysol solution or strong formalin solution. Re-paper and whitewash thereafter.

Water.—Filter through Pasteur-Chamberland or Berkefeld filters, and then boil.

Wells.—Do not trust to potassium permanganate if well is infected. Either add some and boil all water before use (if the well cannot be emptied or no other supply is available); or, if the well can be emptied, add 1 per cent. formalin, scrub, allow to stand, and then pump out.

Or quicklime may be used in the same way, half a barrel being stirred up.

Wool.—Formaldehyde gas.

Standardisation of Disinfectants.

A large number of the disinfectants on the market are of little value unless very concentrated.

There is, unfortunately, no official control over the sale of disinfectants.

Standardisation is very desirable, and must be based rather on a bacterial than a chemical criterion.

As a unit of comparison, the action of phenol is probably the most convenient standard to adopt, and the germicidal values of disinfectants should be expressed in multiples of that unit. As a standard test organism, the spores of anthrax may be used as the most resistant microbe known.

Bacteriological Examination.

Strips of linen are smeared with material containing anthrax spores, and are then exposed for varying times to varying strengths of various disinfectants, and the results with respect to the viability of the test organism are tested both by culture and animal injection, and then can be expressed in terms of phenol value.

According to Koch, a good disinfectant must be rapid as well as certain in its action.

Chemical Examination.

(1) *Carbolic Powders.*—Fifty grammes are extracted with spirit, removing all the acids uncombined with lime. Mix the extract with 50 c.c. NaOH Sol. (10 %). Distil the spirit off and evaporate to 30 c.c. Filter any tar oils which separate. H_2SO_4 (50 %) is added slowly by burette till the soda is ventralised. The tar acids are thus thrown up, and this separate layer can be read off.

Specification for Tender for Supply of Carbolic Powder (after Pearmain and Moor).—"The powder to contain not less than 15 % of tar acids, of which 62·5 % crystallises at 15° to 20° C. by Lowe's test, the base to contain no lime nor chalk."

(2) *Crude Carbolic.*

Lowe's Test.—100 c.c. are distilled by retort (without condenser) at slow rate. The first portion of the distillate will contain all the water and 10 % of the tar oils. A new flash is then substituted, and 62·5 c.c. collected. This is gently stirred and cooled, and the temperature of crystallisation noted. This can be compared with known standard crystallisation temperature.

(3) *Liquid Carbolic Preparations,* such as Jeyes' Fluid, etc.—These are prepared by heating rosin with caustic soda, and stirring in tar oils while hot. An assay may be made by adding 50 % H_2SO_4, which throws up the tar acids, which are then distilled by Lowe's test.

CHAPTER XI

BACTERIOLOGY

The following is the biological status of the lower forms of vegetable life—

Group. Thallophyta.
Class. Fungi.

Order I. Schizomycetes. (Unicellular organisms. Reproduction usually by fission.)
- Family I. Coccaceæ (spherical forms).
  - Genus 1. Micrococci (irregular division).
  - Genus 2. Streptococci (division in 1 plane).
- Family II. Bacteriaceæ (rod forms).
  - Genus 1. Bacteria (no spores).
  - Genus 2. Bacilli (spores).
  - Genus 3. Spirilla (spiral forms. No spores).
  - Genus 4. Vibrios (spiral forms. Spores).
- Family III. Leptotricheæ (unbranching threads).
- Family IV. Cladotricheæ (pseudo-branching threads).
- Family V. Streptotricheæ (branching threads).

Order II. Blastomycetes (yeasts). (Unicellular. Reproduction by budding.)

Order III. Hyphomycetes (moulds). (Multicellular. Spores.)

These lowly forms of life have an enormous distribution, and are found practically everywhere in earth, air, and water.

The coccaceæ and bacteriaceæ are excessively small. Most of them are from one to five micro-millimetres in length. This micro-millimetre is $\frac{1}{25000}$ inch, and is expressed by the Greek letter μ.

The reproduction of these microbes is either by division (fission) or by spore formation. As it takes about an hour for one microbe to divide, and such division is by geometrical progression, the progeny of a single germ becomes over $16\frac{1}{2}$ millions in 24 hours, and at the end of a week the number of germs would run into 51 figures.

Unfavourable conditions—temperature, moisture, or food, etc.—fortunately afford some check to this surfeit of reproduction.

Those which form spores are of considerable danger to mankind, since spores are highly resistant, and will withstand both dessication and much human persecution with impunity.

Many of the bacteriaceæ are motile, and some are furnished with flagella.

As they contain no chlorophyll, they cannot make use of CO_2, as do other plants. They obtain their N both from organic and inorganic matter, and their O from the air or various oxides.

Those which need atmospheric oxygen are called "*aerobic*," while those that live in a non-oxygen atmosphere are called "*anaerobic*." If an aerobe can also live without oxygen it is called a "*facultative anaerobe*," and vice versa. Those bacteria with a special partiality for dead organic matter are termed "*saprophytes*." Those which cause disease in the higher animals or in man are dubbed "*pathogenic*." The disease is not caused by the physical action of the germs, but by the chemical products which they secrete; such products we know as ptomaines, ferments, enzymes, toxins, etc.

Bacterial Resistance.

1. *Dry Heat.*

The researches of Koch and Wollfhügel in 1881 showed that out of a large number of germs experimented with, the bacteria need dry temperatures of 120° to 128° C. (248° to 262° F.) for an hour and a half to be completely killed; while the bacilli, or, rather, their spores, need a temperature of 140° C. (284° F.) for three hours. Such a temperature would scorch most materials, and is therefore not often suitable for practical disinfection.

2. *Moist Heat.*

If the heat applied be moist, very much lower temperatures will kill germs than if it be dry. Bacteria are killed by temperatures varying from 50° to 60° C. (140° F.) for a quarter of an hour, and bacilli by exposure to 100° C. for the same time.

3. *Cold.*

Most germs withstand freezing, often for lengthy periods; their growth is, however, inhibited.

4. *Chemical Action.*

The protoplasm of microbes is attacked by many chemical compounds. The germicidal action depends on the nature of the micro-organism, its nutrition, the presence or absence of spores, the temperature, the medium, and the nature of the chemical. Oxidising and reducing agents are not as potent germicides as is often claimed. As a rule, the more powerful an acid is the better germicide it will be.

5. *Light.*

Dryness and moisture have an opposite effect when combined with light to what they have when combined with heat. When moist, a shorter exposure to *heat* is

necessary than if the heat were dry. On the other hand, if moist, a longer exposure to *light* is necessary to kill the germ than if such germ is in a dry state.

The bactericidal action is due to the short wave-length actinic rays comprising the blue, violet, and ultra-violet parts of the spectrum. Both electric light and sunlight are equally efficacious in such action. That such beneficial action does really take place was shown by the work of Downes and Blount in 1881, and the later conclusive experiments of Marshall Ward.

CULTIVATION OF BACTERIA.

The microbes, which have been generally described above, can be cultivated on various media, and can be identified according to their morphology, behaviour to stains, acid and gas formation, agglutination reactions, etc., etc.

As almost everything around us is alive with these organisms, it is necessary to remove or to kill any extraneous ones which may be present in the tubes, vessels or media in which we wish to grow special organisms under observation. Thus the preliminary to the study of bacteriology is:—The sterilisation of apparatus and the preparation of media.

Sterilisation of Apparatus.

If we killed the existing germs (in our test-tubes or in the media contained in them) by means of chemicals, it would be generally impossible to remove such chemical so that it might not interfere with the growth of the organism we wished to observe.

Advantage, however, can be taken of the fact that bacteriaceæ are killed by heat.

I. *Sterilisation by Dry Heat.*

(a) *Naked flame.*

This means is used for sterilisation of the platinum

wires with which culture inoculations are made; also for the points of forceps, etc.

(b) *Hot Air Chamber.*

There is an outer and inner case of iron. The outer case has a circular hole at the bottom allowing the flame of a Bunsen burner to play on the bottom of the inner case. A thermometer, inserted at the top, registers the temperature in the centre of the chamber.

A temperature of 170° C. for 1 hour will kill most of the current contaminating germs.

The method is used for sterilising flasks, test-tubes, Petre-dishes, etc., but cannot be used for solid media (which would be carbonised), nor for liquid media, which, at the ordinary atmospheric pressure, would not attain that temperature.

II. *Sterilisation by Moist Heat.*

(a) *Boiling.*

Boiling at 100° C. for 1½ hours will sterilise under any circumstances. Five minutes is sufficient to kill most bacteria, though longer will be required for bacilli.

The method is useful for sterilising any water required for bacteriological investigations.

(b) *Steam at* 100° *C.*

This most useful of all methods consists of a tall metal cylinder covered with felt or some other bead conductor. Within is the water, and above is a perforated diaphragm on which vessels, etc., may be placed for sterilisation.

A good form of apparatus is "*Koch's Steam Steriliser.*"

Any medium can be sterilised in this, by 1½ hours' steaming.

In the case of gelatin, which would be damaged by such heat, "Tyndall's intermittent sterilisation" should

be adopted. This consists in sterilising for ¼ hour on 3 successive days. On the first day the bacteria will all be killed. On the second, any spores of the bacilli, which will meanwhile have developed, will be likewise

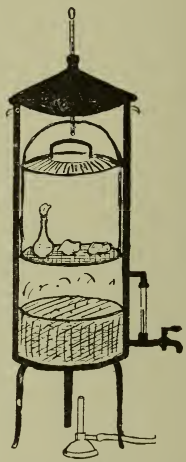

Fig. 30.—Koch's Steam Steriliser.

killed. The third sterilisation is merely a matter of precaution.

Blood-serum and other forms of albumin cannot of course be thus treated, for coagulation would result.

(c) *Pressure Steam.*

This is secured by means of a copper cylinder called an "*Autoclave.*"

This is much the same as a Koch's Steriliser, except that it is strongly built with a clamped top, a pressure-gauge, and a safety valve.

For use, a temperature of 115° C. is attained, and to

boil at this temperature a pressure of about 23 lbs. per sq. inch is necessary (*i.e.* $1\frac{1}{2}$ atmospheres).

Occasionally a temperature of 120° C. is required, when the water will boil at 30 lbs. pressure (*i.e.* 2 atmospheres).

One exposure of $\frac{1}{4}$ hour to such temperature will kill all bacteria and also bacilli and their spores.

Tyndall's method is generally advisable.

Gelatin cannot stand these temperatures.

Certain points in connection with the use of an autoclave should be borne in mind—

(1) The original air should first be expelled before the machine is closed up, otherwise the mixture of air and steam will affect the gauge pressure, and the latter will then not afford an accurate index to the temperature if the instrument is not fitted with a thermometer.

(2) Moreover, if there is no thermometer, there must be a water residuum when steam is up, or else the steam will be superheated, and its temperature will not be indicated by the pressure on the gauge.

(3) Do not open or blow off until the temperature is below 100° C., otherwise the contents will reboil, and the sudden development of steam may blow out the fluid media from the vessels.

(d) *Low temperature.*

Bacteria can be killed by prolonged exposure to a temperature of 57° C. (Muir and Ritchie).

While this method is not adapted for the spore-bearing bacilli, yet it is admirably adapted for sterilising blood-serum, albumin, etc., which would coagulate at a higher temperature.

The apparatus is a hollow cylinder surrounded by a water-jacket. The temperature is controlled by a gas regulator.

The media are exposed to this temperature of 57° C. for an hour a day during eight consecutive days.

Preparation of Media.

The basis of most media is *Liquid Meat Extract.* This is made as follows—

1 lb. of lean meat is cut into strips, minced, pounded in 1 litre of water, heated slowly to 60° C. in a water bath, raised to the boiling point with constant stirring, and after ½ hour is strained through a sieve and filtered into a clean flask. If not required for immediate use, it should be sterilised in a Koch's Steriliser for ½ hour during 3 successive days.

1. *Peptone Broth.*

Take 100 c.c. of the above Liquid Meat Extract and slowly add (to make a thin emulsion) 1 gramme of *peptone* and 0·5 gramme of *Na Cl.*

Place this in a flask and sterilise for 15 mins. in Koch's Steriliser. While hot, $\frac{N}{1}$ soda should be cautiously added, and the flask shaken, till slightly alkaline; 4 c.c. per litre is a usual amount to add after neutralising. The alkalised broth is now sterilised for ½ hour and then filtered into a clean flask.

It is then carefully run into sterile test-tubes, which are subsequently put in a Koch's Steriliser for 20 mins. on 3 successive days. After the 20 mins., the tubes should *not* be allowed to cool *inside* the apparatus or the plugs will be saturated with moisture and grow molds; they should be taken out and allowed to dry in the air.

2. *Gelatin.*

Take 100 c.c. of the Liquid Meat Extract; mix peptone and salt as in the case of peptone broth above, heat in the steamer and add with shaking 10 grammes of the best French gelatin; alkalise as above; allow to cool below 60° C.

It will now be necessary to *clear* the gelatin in

order to remove the meat phosphates which have been precipitated by heating.

This is done by the mechanical coagulation of albumin.

To a portion of the cooled gelatin add an equal quantity of white of egg, and shake in a flask.

Now boil in Koch's Steriliser for about 20 or 30 minutes till the albumin is precipitated, and filter into a clean flask through a hot-water funnel.

Fill 10 c.c. into test-tubes and sterilise as in the case of broth.

3. *Agar Agar.*

Two grammes of powdered agar, one gramme of peptone and 0·5 gramme of NaCl are carefully worked into a thin emulsion with 100 c.c. of warm liquid meat extract. It is then put in Koch's Steriliser for half-an-hour; alkalised; cooled below 60° C. and cleared with egg-albumin as in the case of gelatin. It is then filtered, test-tubed and sterilised.

The precipitation may take as long as $1\frac{1}{2}$ or 2 hours, and is made more easy by autoclaving at 1 atmosphere, although this will turn it brown and impair its nutritive value.

4. *Blood Serum.*

Blood from an animal is clotted and then ice-cooled for 24 hours.

Pipette off the separated serum with sterile pipettes into a sterile separating funnel, and thence run 5 c.c. into prepared test-tubes. The latter are sloped, at 75° C. for one hour, when the serum will be set. This is repeated on two successive days, and then the tubes are incubated at 37° C. for 24 hours. Those tubes found to be sterile can be set aside for use.

5. *Potato.*

Sound potatoes are cleaned, peeled and washed.

Cylinders are then punched out by a cutter—the ends are cut diagonally—they are then washed in alkaline water, dropped into test-tubes with cotton wool below, and sterilised for 20 minutes on three successive days.

6. *Gelatin Agar.*

It is almost impossible to use gelatin in tropical climates, and therefore it is sometimes convenient to use a mixture of agar and gelatin.

Dissolve 6 grammes of gelatin in 1000 c.c. of the liquid Meat Extract, and then add 0·75 gramme agar and dissolve. It is then neutralised and sterilised as before mentioned.

Methods of Cultivation.

For studying the growth of organisms, tubes, dishes, etc., are inoculated, as will be described, and are then incubated in cupboards called "**Incubators.**"

These are kept at two different temperatures.

The Warm Incubator at 37° C. (98·6° F.).

The Cool Incubator at 20° C. (68° F.).

The heat of these is controlled by a *thermostat*, or regulator, which, when the temperature falls causing some mercury to contract, automatically allows more gas to pass, and thus increases the flame and the heat of the chamber.

When the temperature becomes too high, the expansion of mercury automatically closes the gas-supply and lowers the flame.

Other regulators, such as the "Excelsior gas-valve," control the supply of gas by a lever which is actuated by the pressure of ether and other vapours in a flexible envelope.

Cultures are grown either in test-tubes (roll, streak, stab, or shake cultures), or in flat glass dishes with covers, known as Petri Dishes (gelatin or agar plate cultures).

1. *Roll Cultures.*

A test-tube with sterilised gelatin, prepared as directed, is melted by immersion in a water-bath at 40° C. (104° F.).

It is now inoculated by a platinum wire loop. The method of doing this is to rotate the lip of the test-tube in a Bunsen flame ; hold the test-tube in the left hand and blow out the burning cotton wool. Now hold the platinum wire with the right hand ; pass it through the flame till red-hot ; insert it in the culture to be dealt with ; withdraw the plug of the test-tube with the third and fourth fingers of the right hand; insert the platinum needle in the liquid gelatin without touching the sides of the tube; withdraw and replug. The lips of the tube should now be again sterilised in the flame, and the platinum needle sterilised at red heat.

The inoculated test-tube is now held at an angle in some iced water and rapidly rotated between the hands. Thus a thin layer of gelatin solidifies all round the walls of the test-tube.

For these Roll Cultures a *large* test-tube is used.

2. *Streak Cultures.*

Tubes are used in which the agar or gelatin has been obliquely solidified.

Using all the precautions and carrying out the technique of the roll culture except that we do not liquefy, we inoculate the surface of the medium by gently drawing the platinum wire along the centre of

the exposed surface of the medium. The plug is quickly replaced and the lips sterilised.

If gelatin, the culture is then incubated at 20° C. If agar, at 37° C.

According to the nature of the organism so will the growth differ. The colonies may be confined to the inoculation streak, they may form a skin-like ridge, or spread over the whole surface, or grow into the depths of the medium.

3. *Stab Cultures.*

A platinum wire inoculated with the infective material is thrust into an ordinary culture tube of gelatin or agar.

All the usual precautions for sterilisation should be taken during the manipulations.

The tubes are then incubated. If growth occurs only at the surface, the organism is an aerobe. If only at the deeper parts of the puncture, it is an anaerobe. If it grows both at the surface and along the puncture too, it is a facultative anaerobe.

If gelatin is the medium, liquefaction may occur along the line of inoculation with a cup-like liquefaction at the top. The organisms which liquefy gelatin are, roughly, the moulds, staphylococcus, anthrax, tetanus, malignant œdema and cholera.

4. *Shake Cultures.*

Tubes of media are liquefied, inoculated, carefully shaken, and incubated, after being set in cold water.

Certain organisms thus growing in the depths of the medium will give rise to gas formation.

This gas is usually a mixture of H and CO_2.

The *B. coli communis* is a type of the organisms which thus form gas.

5. *Gelatin Plate Cultures.*

Three ordinary sterile tubes of gelatin are liquefied in a water bath at 40° C.

The first tube is inoculated with the infected platinum wire and the contents mixed.

Some of this mixture is used to inoculate tube No. 2; and some of tube No. 2 to inoculate tube No. 3.

The latter is now rapidly poured into some previously sterilised Petri dishes.

To prevent adventitious contamination the operation must be quickly done, the lid of the dish being slightly raised and quickly replaced.

Details should always be written on the dishes, etc., using a glass pencil.

6. *Agar Plate Cultures.*

The process is the same as for the above gelatin plates.

Agar has the advantage of not being liquefied by certain organisms which liquefy gelatin, but the plates are more difficult to manage.

In these gelatin or agar plates the different organisms will give rise to different types of growth. They may be spherical or irregular in outline, they may grow on the surface or in the depth; they may be transparent or opaque; they may be of various colours, or may colour the medium while themselves colourless.

The isolated colonies are sub-cultured in tubes for further observation.

Staining and Mounting of Organisms.

Having isolated an organism by one of the cultural methods described above, it remains further to observe it microscopically.

Its mobility and agglutinative reactions can be studied while alive by means of **Hanging Drop** preparations.

With a platinum wire a drop of broth is placed on a sterile coverslip, and is then inoculated with a minute trace of the organism under observation.

A slide is then taken which is hollow-ground in the centre; it is ringed with vaseline, and the coverslip is inverted over the hollow cavity.

It can now be examined under the microscope.

The edge of the drop is first found with a low power.

The diaphragm is then stopped down and the high power applied.

The mobility and reproduction of the living organism can now be observed at leisure.

Another use of the "hanging drop" is to establish a diagnostic agglutinative reaction.

It is found in various diseases that if a culture of the specific organism of a certain disease be mixed with the blood of a patient suffering from the same disease, the bacilli will clump together; and, if the organism be a mobile one, loss of mobility will occur.

The reaction can also be obtained with dead cultures also.

This reaction was originally discovered, when experimenting with the Typhoid bacillus, by *Widal*, and the diagnostic reaction of that disease is called **Widal's Reaction.**

Its technique is as follows—

A broth sub-culture is made from an Agar culture and is incubated at 37° C. for one night. Nine loopfuls of this broth are placed on a glass slide around one drop of blood taken from a suspected case of typhoid. They are then all mixed together and a "hanging drop" made by taking a loopful of the emulsion. If the case is typhoid, loss of mobility will occur within half-an-hour and the bacilli will become clumped or "agglutinated." A control experiment with normal blood should be carried out at the same time.

Staining of Organisms.

Stains are of three kinds—

Aniline Basic.	*Aniline Acid.*	*Natural.*
Gentian violet Fuchsin Methyl violet Methylene blue Bismark brown Thionin etc.	Magenta Eosin Picric acid Safranin etc.	Hæmatoxylin Cochineal etc.

The aniline dyes are more or less complicated compounds of coal-tar *anilin* ($C_6H_5NH_2$).

In the basic dyes the basic part of the molecule has the most powerful action. They have a special affinity for the nuclear chromatin and are, par excellence, the bacterial stains.

The acid dyes owe their action to the acid part of the molecule, and have a special affinity for formed elements and protoplasm. They are useful therefore as counter-stains for tissues.

To increase the staining powers certain substances, such as phenol, anilin oil, alkalis, etc., are added to the stains, thus acting as *mordants.*

Gentian violet and fuchsin are the two most useful bacterial stains.

The method of use of all these stains will depend on whether the organism is in tissues or smears.

If in *tissues*, the latter is frozen and cut by the razor blade of some form of *microtome*, or instead of freezing they may be hardened in formalin or alcohol and then imbedded in paraffin-wax or celloidin, and then microtomed.

In the case of *smears,* a portion of the culture, pus, or other material is smeared by a platinum wire on a

coverslip or slide. The smear is then fixed by passing three times through a Bunsen flame fairly rapidly. It is then ready to stain, and this can be done by any of the formulæ, as follows—

(a) *Analine Gentian Violet.*

Shake 5 c.c. analine oil in 100 c.c. distilled water. Filter through wetted paper. Add 10 c.c. absolute alcohol and 11 c.c. concentrated alcoholic gentian-violet.

Keep this in a stoppered bottle as a stock solution.

For use: Stain for about 2 minutes.

(b) *Carbol-fuchsin.*

Dissolve 1 gramme of fuchsin in 100 c.c. aqueous (5 %) solution of carbolic acid and add 10 c.c. of absolute alcohol. Keep this as a stock solution.

For use: Dilute with equal parts of distilled water.

Smears will be efficiently stained by being dipped in this solution and removed immediately. Then wash, dry and mount.

(c) *Leishman.*

This is a good blood stain for demonstrating the malarial parasite, blood spirilla, etc.

0·015 gramme of the solid Leishman stain is dissolved in 10 c.c. of methyl alcohol.

A blood film which has been taken on a slide (sec. art.) is treated with a few drops of this stain (without preliminary fixation) and allowed to remain on for ½ to 1 minute. Double the amount of distilled water is then added and the whole allowed to remain for 5 minutes, rotating the slide slightly to mix it.

Then wash off with distilled water, dry and mount.

(d) *Ziehl-Neelsen.*

This is the method used for showing the acid fast bacteria, such as tubercle.

Method—

Stain in hot dilute carbol fuchsin for 5 to 10 minutes. Decolorise in spirit till no more colour comes away.

(NOTE.—The bacilli remained stained.)

Plunge into 20 % H_2SO_4 and quickly wash in water.

(NOTE.—Acid-fast bacteria, such as tubercle, do not lose their stain.)

Stain $\frac{1}{2}$ minute in dilute carbol-methylene-blue.

(NOTE.—This counter-stains the débris, etc., blue, the bacteria remaining red.)

Wash, dry and mount.

(e) *Neisser's Stain.*

This is useful for demonstrating the Klebs-Löffler bacillus of diphtheria.

Two solutions are required—

(1)	Methylene blue . . .	1 gramme
	Abs. alcohol . . .	20 c.c.
	Glac. acet. ac. . .	50 c.c.
	Dist. water . . .	930 c.c.
	Filter.	
(2)	Bismark brown . .	2 grammes
	Dist. water . . .	1000 c.c.
	Filter.	

Method—

Stain in (1) for 1 minute.
Wash.
Stain in (2) for 1 minute.
Wash, dry and mount.

(NOTE.—The Klebs-Löffler bacillus will be brown with blue ends.)

(f) *Gram's Method.*

Two solutions are required—

(1) Aniline gentian violet (*q. v. ante*).

(2)	Iodine . . .	1 gramme
	KI	2 grammes
	Water . . .	300 c.c.

Method—

Stain with (1) for 5 minutes.
Without washing, pour on (2) for 2 minutes.
Without washing, decolorise in absolute alcohol till no more violet colour is seen to come away.
Wash in water, dry and mount.

(NOTE.—In other than pure cultures the film may be counter-stained with eosin.)

This method is a good diagnostic one, for certain organisms remain stained violet when treated as above; others are decolorised.

A useful mnemonic for remembering which organisms are stained is as follows:—

Staphylococcus (all kinds)
Tetanus
Anthrax
Icteroides
Not forgetting Klebs-Löffler and
Streptococcus pyogenes.

Leprosy
Erysipelas
Fränkel's pneumococcus
Tuberculosis.

Nearly all other organisms are decolorised.

IMMUNITY.

By immunity we imply non-susceptibility to a given pathogenic organism or to its toxins.

Such immunity may be inherent in the animal

NISMS

Gelatin - Liquefies Does not)	Gram (+ Stained − Not stained)	Bile Salt Broth	Remarks
+	−		
No growth	−		
−	−		Malta fever
No growth	+	Acid & gas	
+	+	Acid	Commonest organism of suppuration
+	+	Acid	
+	+	Acid	
+	−	Grows	
−	−	No growth	
−	−	No growth	
−	+		Abscesses
+	−		Acute endocarditis
−	+		Sp. cause of Erysipelas
−	+	No growth	Sp. cause of Pyæmia & Puerperal Fever
−	−		Sp. cause of Scarlet Fever
−	+		Sp. cause of Small Pox
+	+	No growth	
−	−		Anthrax
+	−		Malignant Œdema
No growth	+		Leprosy
	−		
	−		
	−		
+	−	No growth	
	+		Tetanus
−	+		Tuberculosis
+	+		
−	−	Acid & gas	Sp. cause of Cystitis & Colitis
−	+	No growth	Diphtheria
−	−	Acid & gas	
+	−	No growth	
−	−	No growth	
−	−		
No growth	−		Influenza
−	−		Chocolate colour. Causes glanders
−	−		Plague
+	−	Acid	Red colour
+	−		
+	−	Acid	
+	−		
−	−	Acid	Enteric fever
−	−	Acid	
−	−		Tick fever.
−	−	Grows	
−	−	Acid	Fowl cholera
−	−		Relapsing fever
−	−		

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CHART OF PRINCIPAL MICRO-ORGANISMS

	Pathogenicity (+ Pathogenic)	Distribution	Aerobic faculty (+ Aerobe – Anaerobe)	Length	Thermal Death Point	Mobility (+ Mobile – Non-mobile)	Spores	Gelatin (+ Liquefies – Does not)	Gram (+ Stained – Not stained)	Bile Salt Broth	Remarks
FAMILY: *Coccaceæ* Genus: *Micrococcus* (division irregular)											
M. agilis		Drinking water		All small cocci		+	No spores	+	–		
M. gonorrhœæ	+	Gonorrhœal pus	+		60°C	+		No growth	–		
M. melitensis	+	Goats' milk	+			+		–	–		Malta fever
M. pnenmoniæ	+	Sputum	±			–		No growth	+	Acid & gas	
M. pyogenes aureus	+	Pyogenic	±		58°C	–		+	+	Acid	Commonest organism of suppuration
M. „ citreus	+	Pyogenic	±			–		+	+	Acid	
M. „ albus	+	Pyogenic	±			–		+	+	Acid	
M. sarcina lutea		Air				–		+	–	Grows	
M. „ pulmonum		Sputum				–		–	–	No growth	
M. „ ventriculum		Vomit				–		–	–	No growth	
M. tetragenus	+	Sputum	+			–		–	+		Abscesses
M. zymogenes	+		+			–		+	–		Acute endocarditis
Genus: *Streptococcus* (division in one plane)											
S. erysipelatus	+	Pyogenic		Cocci	53°C	–	No spores	–	+		Sp. cause of Erysipelas
S. pyogenes aureus	+	Pyogenic				–		–	+	No growth	Sp. cause of Pyæmia & Puerperal Fever
S. scarlatinæ	+					–		–	–		Sp. cause of Scarlet Fever
FAMILY: *Bacteriaceæ* Genus: *Bacillus* (spores)											
B. albus variolæ	+	Pustules		0·6μ		–	All form spores	–	+		Sp. cause of Small Pox
B. anthracis	+		±	6μ		–		+	+	No growth	
B. cyanogenus		Air				+		–	–		Anthrax
B. œdematis maligni	+	Soil	–	4μ		+		+	–		Malignant Œdema
B. lepræ	+		±	3μ		–		No growth	+		Leprosy
B. megaterium		Cabbage		8μ		+			–		
B. mycoides		Soil				+			–		
B. pyocyaneus	+	Pus				+			–		
B. subtilis		Soil, Dust, Hay		6μ		+		+	–	No growth	
B. tetani	+	Soil	–			+			+		Tetanus
B. tuberculosis	+		±	3μ	70°C	–		–	+		Tuberculosis
Genus: *Bacterium* (no spores)											
B. aerogenes capsulatus	+	Soil. Dust. Intestines	∓			–	No spore formation	+	+		
B. coli communis	+	Ubiquitous	±			+		–	–	Acid & gas	Sp. cause of Cystitis & Colitis
B. diphtheriæ	+	Sp. membrane	±	3μ	58°C	–		–	+	No growth	Diphtheria
B. enteritidis	+		±			+		–	–	Acid & gas	
B. fluorescens liquefaciens		Water & air		1·5μ		+		+	–	No growth	
B. „ non-liquefaciens		Saprophytic		1·5μ		–		–	–	No growth	
B. friedländeri	Mice & guinea pigs	± pneumonia	±			–		–	–		
B. influenzæ	+		+			–		No growth	–		Influenza
B. mallei	+		+	2μ		–		–	–		Chocolate colour. Causes glanders
B. pestis	+		+			–		–	–		Plague
B. prodigiosus		Bread & potatoes				–		+	–	Acid	Red colour
B. proteus miribilis		Saprophytic				+		+	–		
B. „ vulgaris		Saprophytic		4μ		+		+	–	Acid	
B. „ zenkeri		Saprophytic				+		+	–		
B. typhosus	+	Water, etc.	±	3·5μ	55°C	+		–	–	Acid	Enteric fever
Genus: *Spirillum* (no spores)											
S. choleræ	+	Water	±	3μ	50°C	+	No spores	–	–	Acid	
S. duttoni	+	Ticks		15 to 40μ		+		–	–		Tick fever.
S. finkler-priori	? +		±	3μ		+		–	–	Grows	
S. metchnikovi	Fowls		±	3μ		+		–	–	Acid	Fowl cholera
S. obermeieri	+	? Bugs or fleas		15 to 40μ		+		–	–		Relapsing fever
S. rubrum		Dead mice Water, Soil				+		–	–		

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(*natural immunity*) or may be acquired either by undergoing an attack of the disease or by artificial inoculation (*acquired immunity*).

As examples of natural immunity we have swine fever, which occurs amongst animals but never amongst human subjects; and typhoid and cholera, which are human diseases, but under natural conditions never occur amongst animals.

As examples of acquired immunity we have smallpox, typhoid, etc., one attack of which confers subsequent immunity.

Theories of Acquired Immunity.

1. *Theory of Exhaustion.*

Promulgated by Pasteur.

The idea being that bacilli by their growth in the body exhaust some necessary pabulum.

The supposition is *disproved* by the occurrence of passive immunity, for a small quantity of exhausted serum could not exhaust all the serum of another animal.

2. *Theory of Retention.*

That the products of metabolism are, after a time, inimical to their further life, and thus an acquired immunity results.

The anti-toxin is in this case probably synonymous with the toxin.

3. *Theory of Phagocytosis.*

Propounded by Metchnikoff.

This is founded on the phagocytic properties of many of the body cells, notably the polymorpho- and large mono-nuclear cells.

By *Chemiotaxis* (or the attraction and repulsion exercised on bacteria by chemical agency), the leucocytes are guided in their attacks on the germs.

In a susceptible animal there is only imperfect phagocytosis ; but if the animal is immunised, active phagocytosis occurs.

It is therefore a result of immunity but not a cause.

4. *The Humoral Theory.*

Due to Behring and others of the German school.

The appearance of immunity is accomplished by the formation of antitoxic and antimicrobic substances in the serum.

These batericidal substances seem to be derived from the leucocytes. This again is therefore rather a result than a cause of immunity.

5. *The Acclimatisation Theory.*

This maintains that the cells of the body gradually assume a toleration for the bacterial toxins, until a condition of immunity is secured.

Natural Immunity.

Toxicity is relative. There is a resistance factor for all animals and persons.

In some cases this index of resistance is so high that there is apparently complete immunity, *e.g.* the common fowl and tetanus. In some cases it is very low, but even then, up to that point there is resistance.

This natural resistance is not capable of explanation, and there is no evidence of protection by antibodies before the poisonous dose is reached. Thus the serum of the fowl does not protect a susceptible animal from the toxins of the tetanus bacillus ; but if artificial resistance has been induced in a more susceptible animal, then the serum of the latter is found to possess antitoxic powers.

The bactericidal power of the serum is, as found by the researches of Buchner, probably due to the presence of certain substances akin to the enzymes and

ferments, and known as *alexines*. These are thought to be derived from the spleen, thymus and other glands. They are destroyed by light and by a temperature of 60° C., and are precipitated by alcohol and by ammonium sulphate.

The bactericidal action of these substances is found to be selective in its action, and moreover by no means varies *pari passu* with the immunity of the animal.

ARTIFICIAL IMMUNITY.

This may be active or passive.

Active Immunity is that produced by a series of injections of non-lethal doses of

(1) attenuated living organisms,
(2) virulent living organisms,
(3) dead organisms,
(4) toxins (*i. e.* filtered cultures).

Passive immunity (or serum therapy) is that produced by injection of the serum of an animal in which active immunity has been induced.

There are two methods by which this passive immunity is secured.

1. By *antitoxic serum.*

That is, the serum of an animal which has been highly immunised by injection of the toxins (filtered cultures).

Such sera have no actual bactericidal properties, but they protect, to a slight extent, from an invasion of the corresponding organism and render its toxins non-effective.

The best-known examples of such sera are those of diphtheria and tetanus.

2. By *antimicrobic serum.*

That is, the serum of an animal which has been

highly immunised by non-lethal injections of virulent living organisms.

Such sera have actual bactericidal properties, and very markedly protect from a corresponding microbial invasion, though they do not render its toxins non-effective.

Examples of these are: anti-streptococcic, anti-typhoid, anti-cholera and other similar sera.

CHAPTER XII

PARASITOLOGY

Of the vast number of parasites which find refuge and support in or on the human frame, only a limited number need be considered by the sanitarian.

The following (omitting bacteriaceæ) will be here mentioned—

Animal Parasites.

1. *Epizootic.*

Demodex folliculorum.
Sarcoptes scabei.
Onithodorus moubata.
Pediculus capitis.
„ vestimentorum.
„ pubis.
Cimex lectularius.
Pulex irritans.
Læmopsylla cheopis.
Dermatophilus penetrans.
Mosquitoes.
Tsetse flies.

2. *Entozootic.*

Entamœba dysenteriæ.
Hæmamœba vivax, malariæ and precox.
Trypanosomata of mammals.

Nematodes.

Trichocephalus dispar (Whip-worm).
Trichinella spiralis.
Ankylostoma duodenale.
Ascaris lumbricoides (Round-worm).
Oxyuris vermicularis (Thread-worm).
Filaria medinensis (Guinea-worm).
„ bancrofti.

Trematodes.

Schistosomum hæmatobium (Bilharzia).
Fasciola hepatica (Liver fluke).

Cestodes.

Dibothriocephalus latus.
Hymenolepis nana.
Tænia solium.
„ saginata.
„ echinococcus.

Vegetable Parasites.

Microsporon audouïni.
„ mansoni.
„ furfur.
Trichophyton endothrix.
„ ectothrix.
„ mansoni.
„ pictor.
Achorion schönleini.
Cladothrix actinomycis.
„ mycetomæ.

Demodex folliculorum.

This is a very small vermiform parasite less than $\frac{1}{50}$ in. in length.

It belongs to the class Arachnida; order Acari (to which the ticks and mites belong).

It lives parasitically in the hair follicles and sebaceous ducts.

It has 4 pairs of three-jointed legs and a long abdomen.

The females are larger than the males.

As a rule it is non-pathogenic but occasionally gives rise to small acneiform inflammation.

An allied species causes refractory cutaneous disease in the dog and pig.

Sarcoptes scabei (or *Acarus scabei*).

This parasite belongs to the class Arachnida; order, Acari; family, Sarcoptidæ; genus, Sarcoptes.

It is the specific agent of the pathological condition known as "scabies" or "the itch."

The legs are submarginal; two pairs are anterior and terminate in suckers; while two pairs are posterior and terminate in spines.

There are several pairs of hairs, the longest being sub-anal.

The female is larger than the male.

After copulation, the male bores just under the epidermis and may be seen as a brown speck. The female burrows some distance into the skin (usually about the digital folds, the buttocks, thighs and genitals) and then lays a dozen or more oval ova at the bottom of the excavation. These hatch into larvæ in about a week.

The larvæ are asexual, have only three pairs of legs, and moult several times before attaining the arachnid complement of legs and sexual differentiation.

Human infection is by direct contact with the infected person or infected linen, clothes, etc.

Ornithodorus moubata.

This is one of the true ticks and the one which has the greatest pathological significance to man, in that it conveys the African "Tick Fever" (*Spirillum duttoni*).

The order Acari to which the ticks belong is divided into two families—

1. Argasidæ.
2. Ixodidæ.

To the former of these families belong most of the ticks which are harmful to man; to the latter family, the genus that conveys Texas-fever of cattle (Rhipicephalus).

The *O. moubata* is one of the Argasidæ. When fertilised, the female drops to the ground and seeks a secluded spot to lay her eggs. This tick is less epizootic than most ticks, and more resembles, in habit, the cimex (or bed-bug), in that it hides in crevices of beds, boards, walls, etc., and comes out at night to suck blood. It is, moreover, less fertile than many other ticks (20,000) and lays less than 200 ova. The female then dies.

In 6 or 8 weeks the ova develop into 6-legged asexual larvæ. They then feed on some warm-blooded host for a few days, and soon after moult, the pupa being 8-legged but still asexual.

Pediculus capitis.

The pediculi belong to the class Insecta; order, Anoplura; family, Pediculidæ; genus, Pediculus.

They have a soft retractile beak with a submarginal row of hooks.

A piercing tube of 4 longitudinal segments can be protruded.

The thorax is small and unsegmented.

There are three pairs of legs.

The *P. capitis* is rather more elongated than the 3 other species and chiefly frequents the scalp hair.

The ♀ lays about 50 grey operculated ova. These ova are mature in about a week, when the young imago emerges.

Pediculus vestimentorum.

This is nearly the same length as the foregoing, but is broader.

The ♀ lays 70 to 80 ova in clothing, etc., and the latter take about a fortnight before a young imago is produced.

They only come to the body to feed.

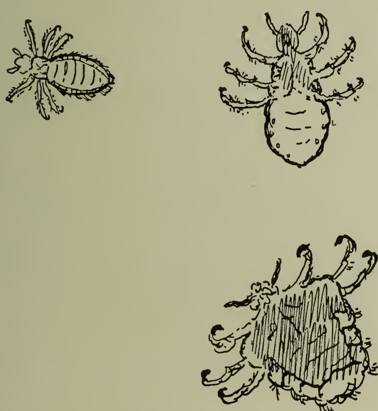

FIG. 31.—PEDICULUS CAPITIS, VESTIMENTORUM AND PUBIS.

Pediculus pubis.

This is almost triangular in shape, with the base forwards.

The legs are furnished with claws.

The ♀ lays about a dozen eggs at the base of the hairs.

Cimex lectularius.

This familiar insect—the bed-bug—also belongs to the class Insecta. The order is Rhynchota; family, Geocorisæ.

They have the usual 3 pairs of legs which pertain to

"insects." The habitat and habits are too well known to recapitulate here.

The ♀ lays about 50 operculated ova, which mature in about a week.

As in the case of the pediculi, there is no larval or pupal stage. The young, however, have 2 or 3 moults before attaining maturity.

Their characteristic odour is derived from two glands in the proximal abdominal segment.

Fleas.

These insects are well known in shape and habits.

They belong to the order Siphonaptera. In this order there are 3 *families*—

I. *Sarcopsyllidæ* (Taschenberg, 1880).

Genera—

(*a*) Dermatophilus (including the *D. penetrans* or Chigoe).
(*b*) Hectopsylla.
(*c*) Echidnophaga.

II. *Pulicidæ* (Taschenberg, 1880). The majority of Siphonaptera belong to this family.

Genera—

(*a*) Pulex (to which belongs the *P. irritans*, or flea of man).
(*b*) Pariodontis.
(*c*) Mæopsylla.
(*d*) Læomopsylla (to which belongs the *L. cheopis* or black-rat flea, by which plague is carried).
(*e*) Rhopalopsyllus.
(*f*) Parapsyllus.
(*g*) Coptopsylla.
(*h*) Goniopsyllus.

(*i*) Lycopsylla.
(*j*) Ceratophyllus (to which belongs the *C. fasciatus*, or brown-rat flea).
(*k*) Ctenocephalus (to which belong the *C. canis* and *C. felis* of dogs and cats, etc.).
(*l*) Etc., etc.

III. *Ceratopsyllidæ* (Baker, 1905). These are all bat fleas.

Genera—

(*a*) Ischnopsyllus.
(*b*) Thaumapsylla.
(*c*) Ctenopsyllus.

Most fleas have nocturnal feeding habits. They keep, as a rule, to their special host; but leave the corpse as it gets cold, and seek a fresh host.

In the case of plague-stricken rats, when any number sicken and die, these rodents migrate to a new neighbourhood. The fleas from the dead rats, having then no other rats to go to, will seek the nearest warm-blooded animal. If the rats happen to have been black (*Mus rattus*), which live with or near man, then the new hosts for the fleas will be ready at hand, and human plague will result. If, on the other hand, the plague had been amongst the large brown rat (*M. decumanus*), which lives underground in sewers, etc., then human plague is less likely to result, for man is not so accessible to the peripatetic fleas.

The ♀ flea lays about a dozen ova in the host's fur, birds' nests, floor-cracks or elsewhere.

In about a week they hatch into caterpillar-like larvæ, which have 14 segments and 10 pairs of stigmata. The larvæ feed on organic refuse or blood; and, in about 10 days, spin a cocoon from which an imago emerges a fortnight later.

In the case of the *Dermatophilus penetrans*, the ♀,

after impregnation, buries herself in the skin of exposed parts of the body, and there swells to a large size, causing considerable irritation and often inflammation.

It is generally stated that fleas have rudimentary wings. This is not the case: there is no clypeus; and in fact there is no trace of wings, either vestigial or rudimentary (Rothschild).

The *antennæ* are 3-jointed, and are placed in fossæ behind the eyes.

The *mouth* has—

(*a*) Hypopharynx, serrated above and tubular below.
(*b*) Two mandibles. Serrated outside and tubular inside, forming with (*a*) a tube.
(*c*) A labium bifurcating into two labial palps which form a shield for (*a*) and (*b*).
(*d*) Two maxillæ, flattened, and with a 4-jointed palp extremity.

The *thorax* has 3 segments.
The *metanotum* has no flap or epiphysis; but the metathoracic epimerum is very large in some species (Rothschild).
The *abdomen* has 10 overlapping segments.

Mosquitoes.

These troublesome diptera are of very wide distribution, and are found in various climates extending from the equator to Greenland.

They are of great importance to the sanitarian, since many of them have been now shown to be efficient intermediate hosts for the malarial parasite, the pathogenic filaria, the virus of yellow fever and probably of dengue.

The following classification of the *Sub-families of Culicidæ* is taken from Theobald.

CULICIDÆ

- **Anophelinæ** (Proboscis straight, Palpi ♂ and ♀ long)
- Orthorhynchæ (Proboscis straight, Palpi short in ♀ variable in ♂)
    - Metanotopsilæ (Metanotum nude)
        - Heteropalpæ (Palpi long in ♂)
            - **Culicinæ** (Wings with 6 long veins)
            - **Heptaphlebomyinæ** (Wings with 7 long veins)
        - Micropalpæ (Palpi short ♂ and ♀)
            - **Ædinæ** (Abdomen simple)
            - **Hæmogoginæ** (Abdomen notched below)
    - Metanototridiæ (Metanotum scaley)
        - Heteropalpæ (Palpi long in ♂)
            - **Hyloconopinæ**
        - Micropalpæ (Short palpi in both sexes)
            - **Dendromyinæ**
- Ankylorhynchæ (Proboscis curved)
    - **Toxorhynchinæ** (Palpi short in ♀)
    - **Megarhininæ** (♂ and ♀ palpi long)

Thus there are nine ultimate sub-families most of which contain a considerable number of genera.

The genera are largely grouped by the type of *scales* which occur on the head, thorax, abdomen, and veins of the wings.

Most female mosquitoes after copulation will seek water on which they lay their ova. (*Prabhamia* lays also on damp mud, and *Dendromyia* on leaves.)

The insects alight on a floating body, and then drop their eggs side by side (often to the number of several hundred) into an acute angle formed by their approximated hind legs; thus a boat-shaped mass is formed, which is allowed to drop into the water.

Some, such as *Stegomyia* and *Mansonia*, lay the ova separately; others, such as *Tæniorhynchus*, in long ribbons.

The ova of the various genera are often of peculiar shapes. The **larvæ** (or well-known "wiggle waggles") appear in 2 to 6 days.

The larvæ have compound eyes; two short antennæ: a large thorax with lateral bristles; an abdomen with nine segments. In most of the sub-families there is a respiratory siphon on the 8th abdominal segment; and, in order to breathe, the larva comes to the surface, protrudes the siphon into the air, and thus hangs head downwards. In the *Anophelinæ*, however, there is no siphon, and the larvæ lie more or less horizontally along the water surface.

Their food consists of algæ, though *Mucidus, Toxorhynchus* and a few others are carnivorous.

After a week or two a **pupa** emerges from the larva.

This pupa can swim but does not eat. There is a large head folded on the thorax, and two large black eyes. The respiratory siphons now open on the thorax.

The abdomen has nine segments, and ends in two broad anal plates.

After a life of 2 to 7 days the pupa rises to the surface, its integument splits, and the **imago** is released, resting for some time on its old pupal skin in order to dry the wings and body properly.

The normal food of the mosquito is the juice of plants. Blood-feeding is merely adventitious, and is only indulged in by the female.

Mosquitoes will breed throughout the year in the tropics. In colder climates there is hibernation. *Grabhamia* ova can live through the winter. Some species of *Anopheles* and *Dendromyia* can survive freezing in the larval stage. In other species, the adult female hibernates and the male dies.

Mosquitoes are largely nocturnal feeders, except *Stegomyia*, and some few others which also feed by day.

The commonest house-mosquitoes are :—*Stegomyia fasciata* and *Culex fatigans*.

The following are the species at present known to be of medical importance :—

Sub-family Anophelinæ.

Anopheles algeriensis.
Anopheles bifurcatus.
Anopheles jesoensis.
Anopheles maculipennis.
Cellia albipes.
Myzomyia culifacies.
Myzomyia funesta.
Myzomyia hispaniola.
Myzomyia listoni.
Myzorhynchus paludis.
Myzorhynchus pseudopictus.
Nyssorhynchus cubensis.
Nyssorhynchus lutzi.
Nyssorhynchus maculatus.
* *Pyretophorus costalis.*
Pyretophorus superpictus.

All the above Anophelinæ have been proved to act as efficient hosts for the malarial parasite.

* *Myzomyia rossii.*
* *Myzorhynchus sinensis.*

Sub-family Culicinæ.

* *Culex pipiens.*
* *Culex ciliaris.*
* *Culex fatigans.*

All the foregoing which are marked * have been proved to act as efficient hosts for the pathogenic *Microfilaria nocturna*.

⊙ *Stegomyia fasciata.*

This has been proved to be the mosquito which conveys yellow-fever.

The species marked ⊙ probably also convey the disease known as dengue.

It will be noticed that malaria is conveyed (as far as is known) only by the Anophelinæ.

This sub-family can, generally speaking, be distinguished from other families by the following characteristics—

(*a*) The wings are spotted by dark aggregations of vein scales.

(*b*) The position of the adult at rest is more perpendicular to the surface on which it stands than the usual horizontal position of other mosquitoes and diptera.

(*c*) The larvæ are asiphonate and lie along the surface of the water when breathing, instead of hanging head downwards as in the case of the other families which are siphonate.

Tsetse-flies.

These important diptera belong to the family Muscidæ, which contains the following genera—

1. *Stomoxys* (stable-flies).—Piercing proboscis long; palpi shorter.
2. *Tabana* (horse-flies).—Palpi almost same length as proboscis.
3. *Glossina* (tsetse-flies).—Very long, straight proboscis.
4. *Musca* (house-flies).—Non-piercing proboscis.
5. *Lucilia* (blue-bottles).—Non-piercing proboscis; thorax metallic.
6. Etc., etc.

The Glossinæ or Tsetse-flies produce full-grown larvæ which live in decaying vegetable matter, and change to pupæ almost immediately.

Their importance lies in the fact that they convey trypanosomiasis (sleeping sickness) to man; and also act as efficient hosts for the trypanosomata of some diseases of the lower animals.

The chief species (after Austen) are—

(*a*) *Glossina palpalis.*—A river fly with a distribution on the Congo, the Niger, Sierra Leone and Uganda.

This species conveys human trypanosomiasis.

(*b*) *Glossina morsitans.*—Distribution: South, Central, and East African.

It conveys a "fly-disease" of domestic animals.

FIG. 32.—TRYPANOSOMA GAMBIENSE.

(*c*) *Glossina fusca.*—Distribution: East and West Africa.

It conveys "ngana," or a fly-disease of cattle due to the *Trypanosoma brucei.*

(*d*) *Glossina pellicera.*—Found in West Africa.

(*e*) *Glossina tachinoides.*—Found in Northern Nigeria and Central Africa.

(*f*) *Glossina pallidipes.*—Found in Central and East Africa.

(*g*) *Glossina longipalpis.*—Found in East Africa.
(*h*) *Glossina longipennis.*—Found in East Africa.

(NOTE.—As yet it is uncertain whether the latter five species can act as intermediate hosts in the transmission of trypanosomal disease.)

Entamœba dysenteriæ (Schaudinn).

This fairly large rhizopod is the specific cause of

FIG. 32A.—GLOSSINA PALPALIS.

"Tropical" or "Amœbic Dysentery" or "Endemic Dysentery," as opposed to the bacillary or epidemic dysentery which is due to the Shiga and para-dysentery bacilli.

It is 25 to 35 μ in size. It is of a greenish colour, and has no cysts. The ectosarc stains intensely, and is highly refractile. The endosarc is coarsely granular.

Within are a mass of vacuoles, and generally many red corpuscles.

The nucleus is about 5 μ in diameter, is placed laterally, and is hard to see in fresh specimens.

It is actively mobile.

It multiplies by the formation of spores at the periphery of the endosarc, and then divides like all amœbæ.

The parasite is found in the stools of patients suffering from endemic dysentery, and also in the contents or walls of the liver-abscesses which so frequently form a sequel to that type of dysentery.

Two other amœbæ are also found associated with the E. dysenteriæ in cases of endemic dysentery—

Entamœba coli (Schaudinn).
Paramœba hominis (Craig).

These are smaller in size, have many morphological differences, and are non-pathogenic.

Hæmamœbæ.

This genus contains the three species of parasites which cause the malarial fever.

They belong to the Protozoa; class, Sporozoa; order, Hæmosporidia; genus, Hæmamœba.

There are several species of this genus peculiar to monkeys, birds, bats, etc., but the human species are probably limited to three—

1. *H. vivax*, the parasite of "benign tertian fever."
2. *H. malariæ*, the parasite of "quartan fever" or "ague."
3. *H. præcox*, the parasite of the "malignant tertian fever."

The following table (*Trop. Med., Hygiene and Parasitology*, Chas. Griffin & Co.) will show the chief morphological differences between the three parasites :—

	H. vivax.	H. malariæ.	H. præcox.
Time of schizogonous cycle	48 hours.	72 hours.	Irregular.
Pyrexia resulting .	Every other day.	Misses two days.	Irregular or continued.
Effect on corpuscles	Enlarged and pale.	Diminished or normal, and normal colour.	Not definite. Parasite small.
Pigment	Fine. Considerable.	Coarse.	Scanty.
Amœboid tendency	Very marked.	Less marked.	Active.
No. of merozoites .	12 to 24.	9 to 12.	Variable, but few.
Site of sporulation	Peripheral blood.	Peripheral blood.	Liver, spleen and bone marrow.
Male sporonts . .	Circular or oval. 10 μ in diameter. Large nucleus central. Lightly-stained protoplasm.	Circular or oval.	Crescent or sausage-shaped. Pigment granules scattered.
Female sporonts .	Circular or oval. 12–16 μ in diameter. Cytoplasm stains deeply.	Circular or oval.	Crescent or sausage-shaped. Pigment granules aggregated round nucleus.
Schüffner's dots (*i.e.* fine red granules throughout infected corpuscle)	Present.	Absent.	Absent. Coarse granules and clefts may occur round parasite.

The parasite has two schemes of reproduction.

One is an endogenous reproduction within the body of its ultimate host (known as Schizogony).

The second type is an exogenous one (Sporogony) in which part of the life cycle is passed within the body of an intermediate host (the mosquito). It is by this latter means that the perpetuation of the parasite's existence is ensured, and that the disease is spread from man to man.

The commencement of the cycle occurs when some sporozoites (or spindled-shaped spores) are introduced

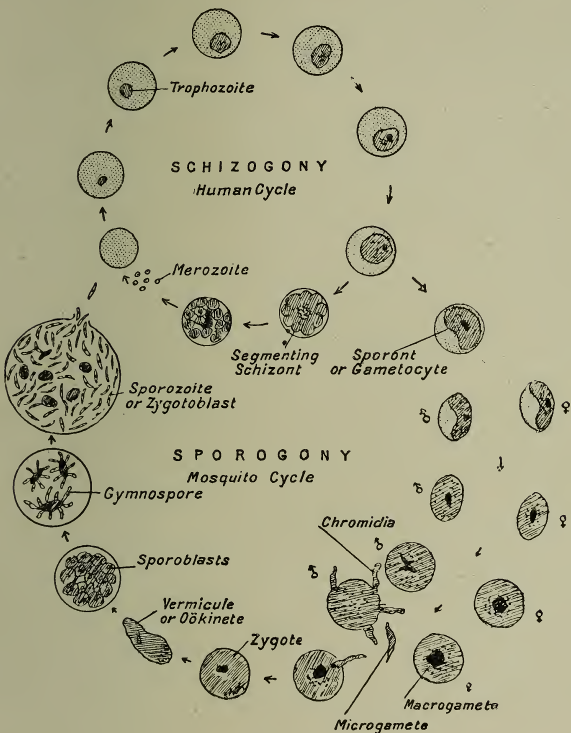

FIG. 33.

through the proboscis of an infected mosquito as it bites a healthy person.

These each attack and enter a red corpuscle, and make an amœboid *trophozoite.* This grows until it fills the corpuscle. Black grains of pigment (*melanin*) are made

out of the hæmoglobin. The full-grown parasite is called a *schizont*. Eventually the pigment collects in the centre, the nucleus divides, the protoplasm segments, and the resulting spores (*merozoites*) break away, and each of them is capable of infecting a new corpuscle, thus completing the schizogonous, or human, cycle.

The febrile reaction which results from the infection, after it has attained certain dimensions, serves as a stimulus for developing out of a few of the trophozoites a sexually differentiated parasite known as a *sporont* or *gametocyte*.

It is this sporont form which, when ingested by a mosquito, can develop within the stomach of that insect.

The male sporonts protrude protoplasmic arms (*chromidia*) which break away and fertilise the female sporonts.

(Note.—The sporonts of the two benign infections are spherical, those of the malignant infection are crescent-shaped. None of them circulate in the peripheral blood until mature.)

The fertilised sporonts are known as *zygotes*. They soon become elongated (*vermicule* or *oökinete*) and pierce the stomach of the insect, developing into a number of spores (*sporoblasts*) which eventually become spindle-shaped *sporozoites* (or *zygotoblasts*) and travel through the mosquito's tissues till they reach the salivary gland, and thence can infect a new human being when the mosquito has its next meal of blood.

Trypanosomata.

These flagellated protozoa have sprung into immense importance since it was found that the fatal human malady known as " Sleeping Sickness " is due to infection by one of the trypanosomal species.

The four most widely distributed species in the

zoological world are none of them pathogenic. They are :—

T. remaki, of the pike fish.—This was found by Valentin, in 1841, and was the first trypanosome discovered.

T. avium, of many birds.

T. rotatorium, of frogs.

T. lewisi, of rats.

The following are the most important pathogenic species :—

T. gambiense. Discovered by Forde, at Bathurst (Gambia) in 1901, in human blood (see Fig. 32).

It is the cause of "Sleeping Sickness," as was first demonstrated by Castellani, in Uganda, who found it in the cerebrospinal fluid of a sleeping-sickness case.

It occurs only in parts of Equatorial Africa.

The length is 18 to 20 μ, breadth 2 to 2·8 μ.

The intermediate host is a tsetse-fly (*Glossina palpalis*).

T. brucei. Causes the fatal cattle disease "Ngana."

Its distribution is South Central Africa.

The length is 25 to 30 μ, breadth 1·5 to 2·5 μ.

Protoplasm has chromatic granules.

Intermediate host is a tsetse-fly (*Glossina morsitans*).

T. evansi. Causes the cattle disease "Surra."

Its habitat is India.

The length is 20 to 30 μ, breadth 1 to 2 μ.

The flagellina is very long.

The intermediate host is the horse - fly (*Tabanide*).

T. equinum. Causes the "Mal de caderas" of horses and donkeys in Central and South America.

The length is 20 to 25 μ, breadth 2 to 3 μ.

The centrosome is very small.

The intermediate host is a fly (*Stomoxys calcitrans*).

T. equiperdum. Causes "Dourine" of horses in Algeria and India.

The length is 18 to 26 μ, breadth 2 to 2·5 μ.

There are no protoplasmic granules. Infection is by coitus.

T. theileri. Causes the "Galziekte" of cattle, in South Africa.

The length is 30 to 65 μ, breadth 2 to 4 μ.

It is one of the largest trypanosomes (except that of 75 μ found by Falshaw in Singapore, 1906, in the blood of a bullock).

The intermediate host is a fly (*Hippobosca rufipes*).

Reproduction in all these trypanosomes takes place by longitudinal division beginning in the centrosome, continuing in the nucleus and undulating membrane, and ending in the protoplasm (Nabarro).

There are no digestive vacuoles, and their nutrition is derived by osmosis.

Movement is due partly to the motion of the undulating membrane and flagellum, and partly to protoplasmic contraction.

Trypanosomes are very sensitive to heat and quickly die at 40° C. or over. They can, however, live for some days at 0° C.—especially the non-pathogenic species.

They can be cultivated in the water of condensation of tubes containing nutrient agar and defibrinated blood. Subcultures show no undulating membrane, and the flagellum is inserted in front of the nucleus (Laveran).

Trichocephalus dispar (Rud. 1801).

This is the common "whip-worm" and is very common in man, also occurring in monkeys.

The male is 40 to 45 mm. in length, about half of which is filiform.

The female is 45 to 50 mm. long and about $\frac{2}{5}$ are filiform.

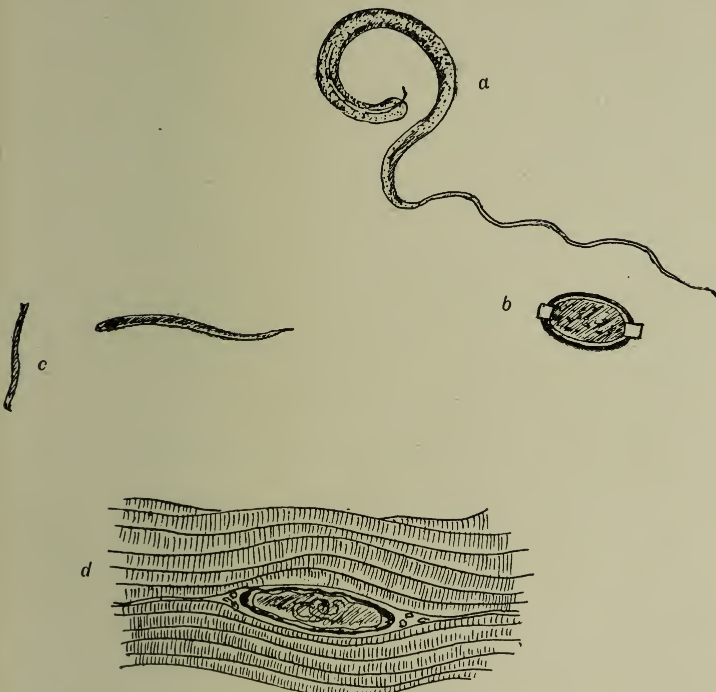

FIG. 34.—TRICHOCEPHALUS DISPAR AND OVUM (*a* and *b*). ♂ AND ♀ TRICHINELLA SPIRALIS (*c*) AND ENCYSTED FORM (*d*).

The ova are perforated at the poles and measure 0·05 by 0·023 mm. They pass out with the fæces and develop in water or moist soil; and, when swallowed by a fresh host, are dissolved, thus setting free the

embryo which takes 5 or 6 weeks to become sexually mature.

Trichinella spiralis (Owen, 1835).

The distribution of this parasite is world-wide. Its normal host is the rat, but it is also frequently found in man and pigs and occasionally in the dog, cat, fox and badger.

The male is 1·5 mm. long and the female 3 to 4 mm.

The small intestine is the usual habitat, and there copulation takes place and the males die.

The impregnated females pierce the mucous membrane and reach the lymph spaces, where, in about 5 or 6 days, they give birth to some 1500 active larvæ.

Thereafter in about 10 days they reach the connective tissue spaces of the muscles, viâ lymph and blood streams, where the irritation gives rise to connective tissue proliferation, and thus they become encysted. Here they can remain alive for some years (11 in the pig and 25 in man).

In the pig it is known as "measly pork," and this is the usual channel of human infection.

When the encysted larvæ are ingested they are freed and develop in the intestine of their new host, thus starting a new cycle.

Ankylostoma duodenale (Dubini, 1843).

This small but important parasite belongs to the order of Nematodes; the family, Strongylidæ; and the genus, Ankylostoma.

The worm lives in the duodenum, fastening on to the mucous membrane by its oval capsule. Blood is absorbed by the worm and the plasma used as food, the corpuscles being evacuated.

Many hundreds of these nematodes may be present, and the host may suffer from severe anæmia in consequence. Monkeys are also frequently infected.

The males are 7 mm. long and 0·5 mm. broad. They terminate in a bell-shaped bursa with dorsal and lateral alar processes. There are 2 long spicules and a bottle-shaped penis.

The females are about 11 mm. long and 1 mm. broad.

FIG. 35.—♂ AND ♀ ANKYLOSTOMA DUODENALE AND OVUM (*a* and *b*). OVUM OF ASCARIS LUMBRICOIDES (*c*). EMBRYOS OF GUINEA-WORM (*d*).

The vulva is at the junction of the middle and posterior quarters. In copulation the worms assume a shape something like a Greek letter γ.

The proportion of males to females is about 1 to 3.

Elliptical ova (see Fig. 35) with thin shells are

produced which measure $60\ \mu \times 40\ \mu$, having a segmented yolk in a transparent fluid. They are evacuated in the fæces, and if the temperature be above 20° C. they will then develop into rhabditiform larvæ, which burst through the shell of the ovum and grow and moult.

Subsequent infection may occur in two ways—

1. By the skin.

The experiments of Looss have shown that the larvæ can enter the skin of coolies and others working with bare feet in infected plantations, and pass viâ the follicles to a blood-vessel, whence they reach the lungs, enter an air vesicle, traverse the air passages, trachea, œsophagus and stomach till they reach their normal habitat, and there develop mature sexual characters. The preliminary dermatitis is known as "coolie itch" or "ground itch."

2. By the mouth.

The larvæ do not stay long in the stomach, but moult twice, and are mature after 2 or 3 weeks.

The cachexia was brought much into public notice by its epidemic occurrence amongst the workmen employed in making the St. Gothard's tunnel. In mining districts it is known as "miner's anæmia."

Ascaris lumbricoides (Linné, 1758).

This is the common human "round worm," and was known to the Latins as *Tinca rotunda,* and to the Greeks as *ἑλμινς στρογγύλη.*

It has a word-wide distribution. It chiefly inhabits the small intestine of man.

The male may attain a length of 25 cm. and the female 40 cm.

There are 3 oral papillæ.

The vulva is at the junction of the anterior and middle-thirds of the body.

The ova, 0·06 mm. × 0·045 mm., are elliptical, rough and darkly stained. They are voided with the fæces, and, after a long incubation in water or moist earth, the embryo develops (see Fig. 35).

Ingestion is the usual method of infection, the embryo taking about a month to develop.

Oxyuris vermicularis (Linné, 1767).

This is the common thread worm, and is of ubiquitous distribution.

It was known to the Greeks as *ἀσκαρις*.

The habitat is the large intestine.

The male is 3 to 5 mm. long and the female 10 mm.

The ova, 0·05 × 0·02 mm., are oval and thin-shelled. When laid the embryo is partially developed. They are voided with the fæces, and may live for several weeks if *not* immersed in water. When ingested the envelope is dissolved in the stomach. The embryo develops and copulates in the small intestine, and then passes to the large.

Filaria medinensis (Velsch, 1674).

This nematode parasite is generally known as the "Guinea-worm," and the condition of human infection as "dracontiasis." The latter name is from the Greek designation *δρακόντιον*, the Latin name for which was *dracunculus.*

Its geographical distribution is limited to West Africa, the Soudan, Red Sea littoral, Persian Gulf, Turkestan and Western India.

The infection is usually single, but as many as 10 worms may occasionally be present.

The adult female is the source of the human trouble. She may attain a length of 80 cm. or more.

Males have recently been found in the monkey, and are much smaller than the females.

The habitat of the adult female is under the skin or in the connective tissue between the muscles. She bores her way by intuition to some part of the body surface which is frequently exposed to the water, such as the foot of a native, the thigh or trunk of a European, the shoulders of the water-carrier.

Arrived there, she drills a hole in the derma, making a small ulcer. The vagina has long been obliterated, and the uterus has lost its contractility as it gradually filled the whole worm with the countless embryos.

The method of extrusion adopted, therefore, by the worm is to protrude the head through the small skin ulcer. When stimulated by the friction of cold water, part of the uterus is protruded from the mouth; ruptures; milky fluid (containing numberless embryos) exuded. This process can be repeated day after day until the uterus of the worm is empty. Until that time the worm resists extraction.

The embryos are 0·6 mm. × 0·01 mm., with a slender tail and rudimentary gut (see Fig. 35). They become very active, and can live for some days in water. They are ingested by a small crustacean—the *Cyclops quadricornis.* Here they moult at about the twelfth day.

Recent work by Leiper has traced the subsequent history.

The embryos can live within the cyclops up to four weeks, when they become quiescent, and soon die.

If now they are placed in gastric juice (or artificial juice = 0·2 % HCl) the cyclops is killed, but the embyro wakes up, darts about, ruptures the cuticle of its host, and thus becomes free.

By this means they reach a new human host; and, once free, quickly attain maturity and breed, after which the males die and the females start on their travels.

Filaria bancrofti (Cobbold, 1876).

These filaria are in appearance much like short lengths of white horse-hair. They were first found by Bancroft, of Brisbane.

They dwell in the main lymphatics of the trunk or extremities.

The male is 80 mm. long by 0·2 mm. broad; and the female 85 to 150 mm. by 0·25 mm.

They have a simple and straight alimentary canal, and the females have a double uterus.

They are viviparous and give forth a large number of small embryos, known as *Microfilariæ nocturna*. These embryos gain the blood stream and circulate in the peripheral blood. They were first discovered in chylous fluid from a hydrocele by Demarquay, of Paris, in 1863; and, in peripheral blood, by Lewis in Calcutta in 1872.

Examinations of the blood show that the embryo parasite is very widely distributed in almost every sub-tropical and tropical country.

They exhibit a strange periodicity, beginning to appear in the peripheral blood at about 8 p.m., attaining a maximum at about midnight, and gradually disappearing by 8 a.m. During the day they retire to the larger blood-vessels. It is estimated that about 40 to 50 millions of these embryos may be circulating. As a rule, however, they are productive of no harm.

The periodicity is probably in the interest of the parasite, to secure removal by its nocturnal-feeding intermediate-hosts (*vide* p. 217). If sleep is taken during the day the periodicity is inverted.

The embryos are 0·3 mm. long by 0·0075 mm. broad. They are enclosed in a loose sheath, which serves to prevent the microfilaria from using its armature prematurely.

The head has six lips. The tail is pointed. Anterior and posterior "V spots" are present. Their motility is lashing and non-progressive.

After a mosquito has ingested some infected blood, the embryo gets free from its sheath, pierces the stomach wall of the mosquito and for 7 days is quiescent, but grows. Eventually it becomes active, reaches the salivary gland of the insect and is injected into a new person when that mosquito next feeds.

The nematodes then find their way to the lymphatics where sexual congress occurs, and countless embryos soon make their appearance.

Mechanical obstruction of lymphatics by the parent filaria will give rise occasionally to many pathological conditions, such as—

Lymphangeitis.
Varicose groin glands.
Lymph scrotum.
Chyluria.
Elephantiasis.
Chylous ascites.
Chylous diarrhœa.

Schistosomum hæmatobium (Bilharz, 1852).

The parasite is one of the trematodes, but differs from most of them in being bi-sexual (see Fig. 36).

It was discovered by Bilharz in Cairo in 1851.

Its geographical distribution comprises almost all the continent of Africa, Mauritius, Syria, Arabia, Cyprus. Cases have also been reported from China, the Malay Peninsula, and the West Indies.

Its biographical status is: Class, Trematoda; order, Malacocotylea; family, Schistosomidæ; genus, Schistosomum; species, S. hæmatobium (often called Bilharzia hæmatobium).

The male is about 12 mm. long, and is whitish and flattened.

Near the anterior end are two discs, oval and ventral. The lateral edges curve in ventrally to form an almost

closed canal (the gynæcophoric canal) in which the filiform female reposes during copulation.

The females are pointed at each end and are about 20 mm. long.

The habitat of the parasite is in the portal vein with its tributary branches, especially those of the bladder and rectum. The number of adult worms may often be large (? 300) and their life may extend to a good many years.

After impregnation the females descend towards the bladder and rectum to deposit their ova.

These ova are of oval shape, yellowish and transparent. They are usually about 0·15 mm. long, and are furnished with a terminal (sometimes lateral) spine.

Within the ovum is a ciliated embryo—*miracidium.*

With their spines the ova bore through capillaries and form bilharzial infarcts, by the rupture of which they can reach the urine or fæces.

On reaching liquid, the miracidia rupture their shell and swim about.

There is probably an intermediate stage passed within some small crustacean (as the guinea-worm in cyclops); or, possibly, like the larvæ of ankylostoma, they may be able to enter by the skin follicles.

The pathological results are—

1. *Hœmaturia.* The last few drops of urine are blood-stained and contain ova.
2. *Urinary fistulæ.*
3. *Rectal excrescences.*

Fasciola hepatica (Retz, 1786).

This hermaphrodite trematode is the common distome or "liver fluke" which occurs as a parasite of herbivorous animals in most parts of the world.

It is highly pathogenic in sheep, and is only a casual (23 cases) parasite of man.

It is a fairly large trematode, being 25 mm. long by 10 mm. broad.

The ova are operculated, yellowish-brown, oval in shape, and measure 0·132 by 0·07 mm.

These ova on reaching water are ruptured by the enclosed ciliated miracidium, which thus becomes free,

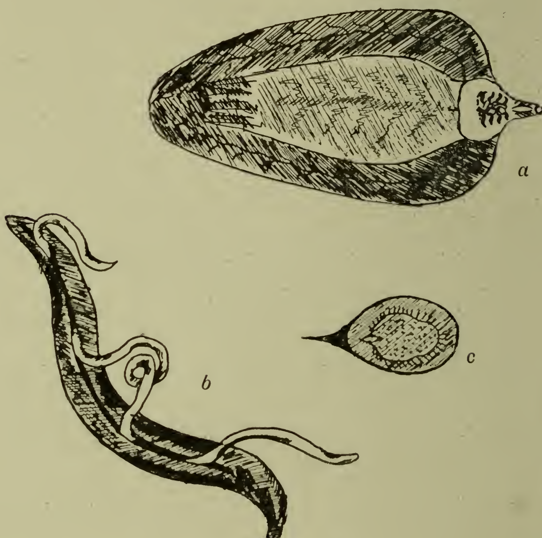

FIG. 36.—FASCIOLA HEPATICA (*a*). BILHARZIA ♂ AND ♀ AND OVUM (*b* and *c*).

swims about and enters a small snail—*Limnæus truncatulus.* Here it loses its organs and becomes a *sporocyst.* This is of a tubular or fusiform shape and contains germinal bodies.

It then becomes a *redia*, in which there is an alimentary canal and a genital orifice.

The redia develops into a *cercaria* which has eyes, a

boring spine, suckers, an alimentary canal, an active and powerful tail; but no genital organs.

The cercaria now becomes free, and either seeks a new intermediate host in which it becomes encysted, or else is ingested by a new definitive host, thus finding its way into the intestines, bile duct, etc., where it soon develops into an adult trematode.

Dibothriocephalus latus (Linné, 1748).

This is the largest human cestode or tapeworm, and may attain a length of 16 metres. It has an almond-shaped head 2 or 3 mm. long.

Man is the usual definitive host, but the dog, cat, and fox can also act as such.

The distribution is wide throughout Europe, Central Asia, Central Africa, and Japan.

The proglottides are broader than they are long, and may number 4000 or more, and grow at the rate of 30 or more a day.

The genital pore is central.

The ova are large (0·07 × 0·045 mm.) and are voided with the fæces (see Fig. 37).

The embryos take several weeks to hatch out in water.

The primary intermediate host is not known, but the cysticercus stage is passed in the tissues of various fresh-water fishes, such as the perch and pike.

Hymenolepis nana (v. Sieb, 1852). (See Fig. 37.)

This is the smallest human cestode. It was first found by Bilharz in Cairo in 1851, and is found in Europe, S. America, Siam, Japan, etc.

The development and infection are unknown.

The worm is 10 to 15 mm. long by 0·5 mm. broad.

The rostellum has a crown of 30 hooks.

The proglottides are short and broad, and number 150.

The ova are 0·035 × 0·05 mm. and of oval shape.

Tænia solium (Linné, 1767). (See Fig. 37.)

The geographical distribution of this cestode is coterminous with the distribution of its cysticercal host—the pig.

The length of the worm is from 2 to 3 metres or more.

It has a globular head with a rostellum of 28 hooklets in a double row.

There are 4 hemispherical suckers.

Proglottides are about 850 in number and are 11 mm. long by 5 mm. broad.

The genital pores are lateral and alternate.

The uterus is branched.

The ova are globular (0·035 mm.).

The habitat of the adult is the small intestine. The ova are voided with the fæces of the host. They are then ingested by the pig, in the stomach of which the egg envelope is dissolved and the embryo thus set free.

The latter bores its way into the muscles, loses its hooks, develops into a head and becomes encysted.

If such infected pig's flesh (which has not been cooked above 50° C.) is ingested by man, the cysticercus attaches itself to the small intestine and proglottides begin quickly to form, thus making an adult.

More than one *T. solium* may be present in the same person.

Tænia saginata (Goezc, 1782). (See Fig. 37.)

This is the commonest and most widely distributed of all the cestodes. Its synonym is *T. mediocanellata.*

The length averages up to 8 metres.

Its habitat is the small intestine.

The head is cubical, with a diameter of 2 mm.

It has 4 suckers, which are hemispherical and pigmented.

There is a pseudo-sucker instead of the rostellum.

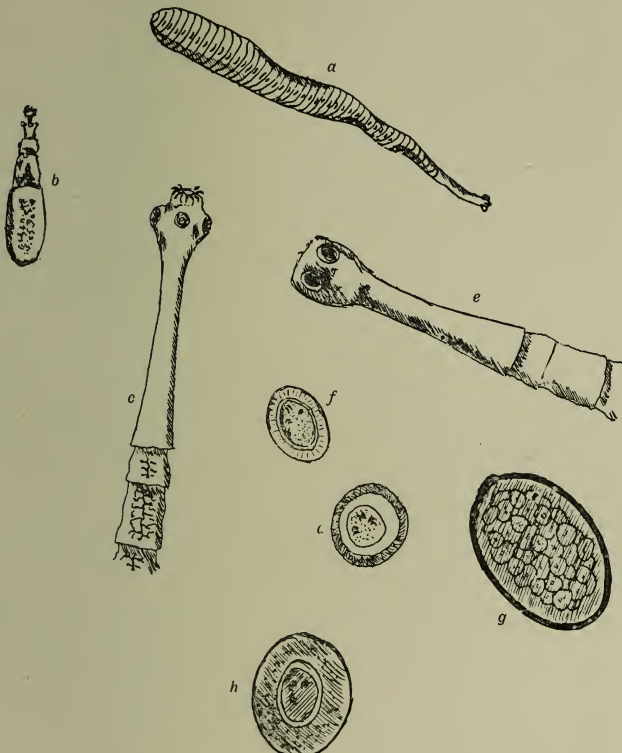

FIG. 37.

(*a*) Hymenolepis nana. (*b*) Tænia echinococcus. (*c* and *d*) Scolex and ovum of Tænia solium. (*e* and *f*) Scolex and ovum of Tænia saginata. (*g*) Ovum of Dibothriocephalus latus. (*h*) Ovum of Hymenolepis nana.

The average number of proglottides is over 1000, and they are about 18 mm. long by 5 mm. broad.

The genital pores are irregularly alternate and are placed laterally.

The uterus is branched.

The ova are transparent and oval—0·04 by 0·03 mm.

They form cysticerci (as does *T. solium*), but the cysticercal host is the ox.

This species is rarely found as a human cysticercal infection.

It is rare to find more than one adult worm in man.

Tænia echinococcus (v. Sieb, 1853). (See Fig. 37.)

The normal host of this small cestode is the dog, and it is also found in the jackal and wolf.

The length of the worm is only 5 to 6 mm.

The rostellum has a double row of 28 to 50 hooklets.

There are 4 round suckers.

The neck is short and there are only 3 or 4 proglottides.

The genital pores are alternate.

The ova are spherical (0·035 mm.).

The cysticercal stage is passed in the liver, lungs, or other organs of many different mammals—especially pigs, sheep, and oxen.

Man is occasionally (in Iceland, Europe, Australia, and Africa) infected with the cysticercus, probably always contracted by the infected caresses of dogs.

Microsporon audouïni.

This causes most of the scalp ringworm in England, and is more rare in the East.

It occurs as a white sheath round the stumps of broken hairs.

The spores are quite small and form a mosaic on the hair.

With them is some mycelium, the hyphæ of which are long, curved, and irregularly jointed, branching

segments which invade the interior of the hair when the cuticle has been eroded.

Microsporon mansoni.

This is the cause of the condition known as "Pityriasis nigra" of Ceylon, Malaya, and China.

The fungus has short threads of mycelium $20\ \mu \times 2\frac{1}{2}\ \mu$, which are irregular, bent, or banana-shaped.

The spores are spherical and large (5 to 8 μ) and frequently aggregated in clusters.

Microsporon furfur.

This is the cause of "Pityriasis versicolor."

The fungus is much like *M. mansoni*, but has much smaller spores which often do not form clusters.

Trichophyton endothrix.

This causes a certain number of European and Eastern scalp and skin lesions.

The infected hairs break, leaving swollen and dark stumps.

Microscopically the filaments consist of spores joined end to end in chains.

The spores are within the hair and do not form a sheath round it. Thus the cuticle is intact.

Trichophyton ectothrix.

This causes the common body ringworm of the tropics (*Tinea circinata*); and probably dhobie itch also.

It much resembles the endothrix, but is of slower growth, and the spores are often smaller. In hairy parts an outside sheath of spores is formed as in the *M. audouïni.*

Trichophyton mansoni.

This causes the scaly skin disease of the East known as "Tinea imbricata."

Trichophyton pictor.

The specific cause of "Pinta."

Achorion schönleini.

The cause of "Favus."

The fungus is rather rare in man, but common in donkeys, horses, birds, etc.

The interior and exterior of the hairs are affected, which causes them to become brittle and break.

Cladothrix actinomycis.

Has long been known in cattle.

It is found in the liver, lungs, tongue, jaw, etc., where it forms nodules not unlike tuberculosis.

It liquefies gelatin.

It is stained by Gram.

It is easily reproduced in the lower animals, and is markedly benefited by pot. iod.

Cladothrix mycetomæ.

Is the cause of the human condition known as "Madura-foot."

The foot, leg, or hand become enlarged, disintegrated, and form cavities and sinuses which discharge black or yellow granules.

The species does not liquefy gelatin.

It is decolorised by Gram.

The lower animals are immune, and pot. iod. has no effect on the condition.

FIG. 38.—WATER SEDIMENT—ORGANISMS FOUND IN.

a a Actinophrys Sol.
b Desmids
c Speirogeira
d Euglena viridis
e Closterium
f Protococcus viridis
g Vorticella
h Beggiatoa
i Volvox globator (segment of the circular organism)
j Draparnaldid
k k k Diatoms

CHAPTER XIII

PERSONAL AND SCHOOL HYGIENE

I. PERSONAL HYGIENE.

1. **HABITS.**

Habits are of importance, since they may predispose to disease or aid longevity.

Eating and Drinking.

With regard to *eating*, the following points should be noted :—

a. Keep the teeth in good condition.
b. Chew the food well.
c. Eat slowly.
d. Eat at regular intervals.
e. Avoid excessive use of condiments.
f. Less work, less food.

With regard to *drinking*—
Water is the basis of all beverages, and is itself the best beverage if pure.

Alcohol.

1 to $1\frac{1}{2}$ fl. oz. of pure alcohol can be absorbed per diem without traces being apparent in the urine.
Such amount should, therefore, be the limit of daily use as a beverage.
Its use by the young is very injurious.

In small doses it will aid digestion, but has an opposite effect in large doses.

Its heat value is 7 food-calories per gramme.

It should never be taken during hard mental or bodily work, but only on completion.

One of the secrets of health in the tropics is—not to drink until the sun goes down.

Smoking.

Is decidedly injurious if indulged in before eighteen years of age. After that time, if used in moderation, its results are sometimes beneficial.

In excess it acts as a cardiac poison, and also will sometimes cause amblyopia.

Sleep.

Periodical rest is necessary for mind and body.

Small children	need	12	hours.
School girls and boys	„	9	„
Adult females	„	8	„
„ males	„	7	„
Past middle age	„	8	„
Old age	„	9	„

The sleep should be taken on raised beds without flounces, in order to allow free circulation of air under and around the bed; and also to avoid any noxious ground air which may have collected.

Bed-hangings should be avoided like poison, and the bedroom windows should be left open summer and winter, though the bed should not be placed in a draught.

2. **WASHING AND BATHING.**

Baths may be of various temperatures—

Cold bath, below		65° F.
Tepid bath	„	85° F.
Warm bath	„	105° F.
Hot bath, above		105° F.

Cold baths should not be taken by those suffering from morbus cordis, nephritis, hepatitis, or various cachexias, nor by those of advanced age.

Residence in the tropics is no bar to the use of cold baths (except under the above circumstances) especially since the temperature of the water will rarely come within the above definition of a *cold* bath.

Vapour and Turkish Baths consist of exposure to a moist heat in various rooms rising from 100° to 200° F. The action of the skin is thereby vigorously encouraged; and a subsequent cold plunge will contract the cutaneous vessels and cause increased activity of the internal organs.

Bathing should not be indulged in on a very full or quite empty stomach.

3. CLOTHING.

The objects of clothing are—

1. Protection from cold, heat, or wet.
2. Maintenance of warmth.
3. Protection from injury.
4. Adornment.

The following are the usual clothing materials:—

(a) *Vegetable Origin.*

1. **Cotton.** The down surrounding the fruit of a *Gossypium*—a tropical shrub cultivated in U.S.A., Brazil, India, Egypt, etc. Cotton is manufactured into *calico, crape, sateen, drill,* and *flannelette.*

The fibres are mainly cellulose, and are about ½ in. to 1 in. long. They are cleaned, spun into yarn and woven.

When mixed with wool it forms *merino.*

The filaments are flat and ribbon-like, about $\frac{1}{1000}''$ broad, and are always twisted.

Cotton is durable, and does not shrink. It is thin

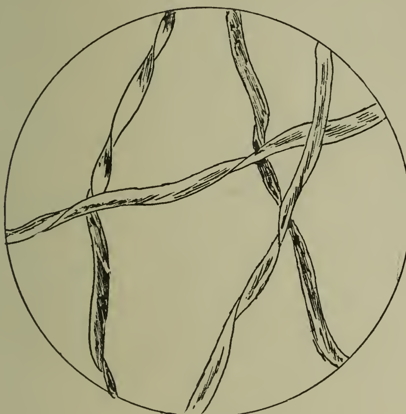

FIG. 39.

and light. The fibres are unirritating. It absorbs water quickly and parts with it quickly.

If changed frequently and protected by outer garments, cotton articles form the best underwear for the tropics.

2. **Flax.** The fibre of the *Linum usitatissimum* (linseed), which grows in Russia and Ireland. The stalks are fermented and then combed, when they yield about 60 % of flax fibre.

It is chiefly manufactured into *linen, cambric, holland, drill, tow, thread,* etc.

Under the microscope the fibres are round, the diameter being rather less than $\frac{1}{1000}''$. They are transversely striated.

Linen is extremely absorbent of moisture, though less so than cotton.

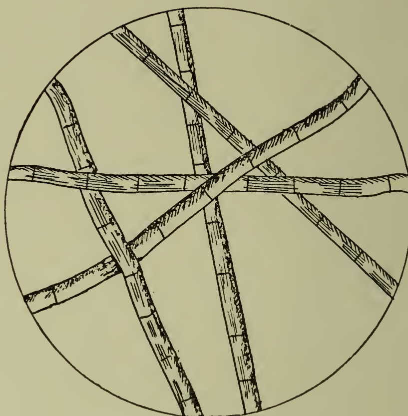

FIG. 40.

A fine cambric is a cool, durable, light, and efficient material for underclothing, both in tropical and summer-temperate climate.

3. **Jute.** A fibre from the *Corchorus capsularis*, chiefly grown in India. It is somewhat coarse, and is used for native garments and for adulterating silk and other fibres.

(b) *Animal Origin.*

1. **Wool.** A modified form of hair obtained from sheep, camels, etc.

The wool of the Angora goat is called *mohair*. The Peruvian sheep gives *alpaca*. *Cashmere* is the wool of the Thibet goat.

Wool is manufactured into *flannel, cloth, blankets*, etc. It hardens and shrinks on washing.

The fibres are round, rather more than $\frac{1}{1000}''$ in diameter, and all imbricated.

Flannel is a very valuable material for underwear in cold climates. Its rough imbrications are a valuable stimulus to cutaneous circulation. Its non-absorbent properties do not matter, owing to the scanty perspiration in a cold climate. The air interstices form a buffer for retaining warmth and excluding cold.

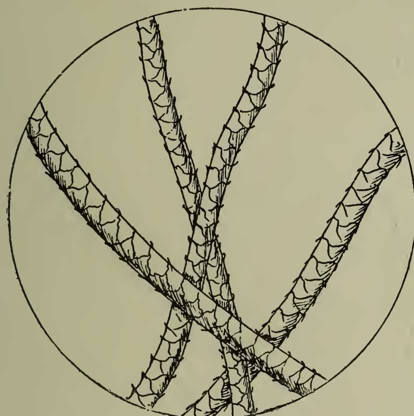

Fig. 41.

In the tropics it is the worst possible underwear. The irritation causes endless "prickly heat." It absorbs moisture very badly, and when absorbed does not evaporate it quickly; consequently there is a layer of moist air kept next to the skin which unduly checks further perspiration.

Flannel has the disadvantage of hardening and shrinking on washing.

2. **Silk.** This is the fibre spun by the larvæ of certain moths from two glands. Each larva produces about 4000 yards.

The following are the moths:—

Bombyx mori	China	Mulberry feeders
B. textor	India	
B. fortunatus		
B. cræsi		
B. arracanensis	Burmah	
B. sinensis	China	
Antheræa peruyi	Mongolia	Oak feeder
A. mylitta	India	Feeds on other trees

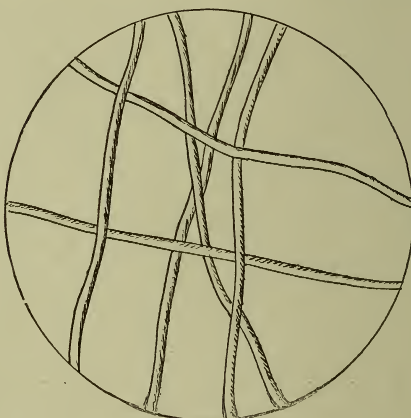

Fig. 42.

The silk fibre is microscopically structureless. It is only about half the diameter of linen fibre, and has no markings or scales.

Silk is a common element in clothing material, and is made up into *silk, satin, velvet, ribbons, gloves, stockings*, etc.

It is an ideal underwear for the sub-tropics, or warm seasons in temperate climates.

It absorbs moisture more rapidly than wool, but less so than the vegetable fibres, and is therefore inferior to cotton for the tropics.

It is smooth and soft, and does not retard skin action as does flannel.

Its chief disadvantage lies in its great expense.

3. **Leather.** The tanned skin of animals, which is used for several clothing purposes—*Boots, shoes, gloves,* etc.

Boots, shoes, and gloves should never be sufficiently tight to interfere with the proper circulation of the hands and feet.

CHEMICAL REACTIONS ON FIBRES.

Reagent.	Wool.	Silk.	Cotton.	Flax.
Hot NaOH conc. .	Dissolves	Dissolves	Nil	Nil
$ZnCl_2$ hot conc. .	Nil	Dissolves	Nil	Nil
H_2SO_4	Nil	Slow sol.	Gelats.	Gelats.
PbO in alk. sol. .	Darkened	Nil	Nil	Nil

4. EXERCISE.

Exercise is necessary to the maintenance of health.

The following are some of the *results* of exercise :—

1. Skin evaporation is increased.
2. Heart-beats increased. (More blood to body.)
3. Respirations increased. (More O inspired; more CO_2 expired.)
4. Metabolism of muscle increased. (Reaction becomes acid instead of neutral.)
5. Intestinal peristalsis increased.
6. Appetite and digestion improved.

The exact amount of exercise necessary will depend on the age, sex, constitution, and avocation of the person.

Those whose avocations imply physical work in the open will probably, *ipso facto*, have had enough exercise.

A fair *day's work* for an average man is put at 300 ft. tons. This is about equivalent to walking fifteen miles (at the rate of about three miles an hour).

A hard day's work is put at 550 ft. tons, or a walk of 24 miles at the above rate.

A navvy will do from 500 to 600 ft. tons per diem on occasions, equal to a walk of 32 miles.

The exercise of those engaged in sedentary occupations should be about 100 ft. tons per diem, equal to a six-mile walk.

Haughton's experiments have shown the **resistance due to traction,** which varies with the velocity of the work.

Work done walking 20 miles @ 1 m. per hr. = $\frac{1}{38}$ work done in direct ascent.
Work done walking 20 miles @ 2 m. „ = $\frac{1}{26}$ work done in direct ascent.
Work done walking 20 miles @ 3 m. „ = $\frac{1}{20}$ work done in direct ascent.
Work done walking 20 miles @ 4 m. „ = $\frac{1}{16}$ work done in direct ascent.
Work done walking 20 miles @ 5 m. „ = $\frac{1}{14}$ work done in direct ascent.

II. SCHOOL HYGIENE.

The structure and arrangement of schools will be considered in Chapter XV. In this section the personal hygiene of the scholar is alone dealt with.

Children at school will be subject to diseases—

(*a*) Incidental to their age.
(*b*) Incidental to their surroundings.

The following points have to be considered :—

(*a*) Uncleanliness of person.
(*b*) Uncleanliness of workrooms or dormitories.

(*c*) Ventilation of workrooms and dormitories.
(*d*) Lighting of workrooms.
(*e*) Arrangement of desks and seats.
(*f*) Print used in school books.
(*g*) Number of hours' work required.
(*h*) Occurrence of infectious disease.

Uncleanliness of Person.

This will favour the spread of ringworm, pediculi, and such parasitic diseases.

Uncleanliness of Buildings.

This will favour the spread of tuberculosis, ophthalmia, diphtheria, etc. All class-rooms and dormitories should be swept daily and scrubbed once a week.

Ventilation of School Buildings.

Free ventilation should be secured by a combination of Tobin's tubes and MacKinnell's ventilator in *every* class-room used for more than twenty boys. The temperature should be kept at 60° F. summer and winter. Closed stoves should not be employed.

Deficient ventilation will predispose to the spread of many diseases, especially tuberculosis.

Lighting of Schoolrooms.

A schoolroom should not be lighted from one side only. Top lighting is undoubtedly best.

Bad lighting is not good for the biological condition of the air, and, if combined with the use of small print, may conduce to myopia.

The window area will vary with the situation of the windows, etc. The following (Morris) is the best formula—

$$\textit{Area of windows} = \sqrt{\text{length} \times \text{breadth} \times \text{height of room}}$$

Blackboards should be of a dull black in order to avoid the eye-strain from a glazed surface.

The Print in School Books.

Small print, combined with bad lighting and long hours, may conduce to eye-strain and myopia.

No type of a smaller size than "*pica*" should be used.

Hours of Work.

The brain does not begin its rapid development until after the age of six or seven.

Until that age, therefore, the education should be more directed towards cultivating the powers of observation and deduction than those of reflection and memory.

Four hours' work is the maximum daily amount which should be allowed for children under 10; five hours for those under 14, and six hours for those under 16.

Arrangement of Desks.

Each scholar should have a desk to him- or her-self. It should be lighted from above or from the left-hand side.

The seat should be of cane, of 10 inch breadth, and fitted with a back reaching just below the scapulæ; its height from the ground being the same as the length of the scholar's leg from the sole of the foot to the knee. The vertical line of the edge of the seat should not be more than 1 inch away from the vertical line of the edge of the desk.

The height from the seat to the desk should be one-sixth the height of the scholar.

The desk should be sloped at an angle of 20° for writing and 45° for reading.

Occurrence of Infectious Disease.

The occurrence of infectious disease may demand :—

(*a*) Exclusion of certain scholars.
(*b*) Closure of schools.

The most usual diseases for which the latter, or sometimes only the former, of these measures may be required are, in the order of their frequency :—

1. Scarlet fever.
2. Measles.
3. Diphtheria.
4. Whooping-cough.
5. Small-pox.
6. German measles.
7. Enteric (rare).

Exclusion of certain scholars, without question of closing the school, may be required in :—

1. Chicken-pox.
2. Mumps.
3. Ringworm.

Any child suffering from any disease in the above two lists should be at once excluded from school.

If a day boy or girl, they should be not only excluded but also all those coming from the same house or its immediate vicinity.

If a boarder, it may be necessary to isolate for observation those in the same dormitory.

The M.O.H. must of course be at once notified of the occurrence of such infectious disease.

If the first cases are few and are early recognised and traced, then exclusion will probably suffice.

Under the code of the Education Council, it is always possible to close Elementary and Public schools.

Sunday schools and private schools may be closed if Secs. 21 and 126 of the P.H. Act, 1875, be contravened.

All scholars returning to school should bring a Health certificate, from a parent or medical man, to the effect that the child has not suffered from any infectious disease during the preceding six weeks, and that no cases of such disease have occurred during that period in any house in which the child has been resident.

The following is the modified (Lewis and Balfour) *table of quarantine* approved by the Association of Medical Officers of Schools:—

Disease.	Quarantine after last exposure.	Earliest return to school, after commencement of attack.
Scarlet fever . . .	8 days.	8 weeks, if *well.*
Measles	16 ,,	3 ,, ,,
Diphtheria . . .	12 ,,	3 ,, ,,
Whooping-cough .	21 ,,	6 ,, ,,
Small-pox. . . .	18 ,,	2 ,, *after scabs gone.*
German measles .	16 ,,	3 ,, if well.
Enteric	21 ,,	8 ,, ,,
Chicken-pox . . .	18 ,,	After scabs all gone.
Mumps	24 ,,	4 weeks, if well.

CHAPTER XIV

GEOLOGY

A CERTAIN amount of geology, as of meteorology, is necessary for the student of hygiene.

For purposes of water-supply, sites of houses, spread of disease, etc., it is necessary to know the effects of the geological agents—rain, rivers, ice, sea, earthquakes, volcanoes, etc.

Some knowledge of structural geology is also required ; also the nature and origin of soils and subsoils, and the structure of the commoner minerals and rocks.

In studying geology, we have unfolded to us a marvellous panorama stretching back through untold centuries.

We see the outer crust of the earth to be composed of many superimposed strata, each representing the earth's surface during the vast epochs of time.

At one time our planetary system was merely a nebulous mass of incandescent vapours and gases and meteorites.

As gradual condensation occurred, the planets came into existence one by one, from without inwards, and the disruption of secondary rings formed the satellites.

At last the whole system was formed and began to cool as its components rotated century after century round the remaining hot nucleus of the original nebula —which we call the sun.

For some hundreds of thousands of years the earth

surface has been sufficiently cool to support life, but the existence of volcanoes, hot-springs, etc., show that the temperature is high at no great distance below the surface, and probably at a depth of 20 or 25 miles there is a higher temperature than molten iron.

The earth is flattened at the poles and bulges at the equator (oblate spheroid), due to its rotational movement when it became detached from the parent nebula.

The present rotation is once in twenty-four hours, but 57,000,000 years ago the rotation was nearly four times as fast, and the length of the earth's day was only $6\frac{3}{4}$ hours. At that time the distance of the moon was only 35,000, instead of the present 239,000 miles.

Of these early ages of the earth's history no geological record has been preserved, for many early crusts would break up and sink back into the molten mass before the formation of one whose strength would be sufficient to form a permanent surface.

The following scheme will show the order of strata in the geological record :—

Post Tertiary.	Recent.	
	Prehistoric.	
	Pleistocene[1] .	Remains of primitive man.
Kainozoic (Tertiary).	Pliocene.	
	Miocene.	
	Eocene.[2]	
Mesozoic.	Cretaceous[3] .	Dicotyledonous flora appears.
	Jurassic . .	Birds found.
	Triassic . .	Mammals appear.

[1] Perpetual arctic frost and snow had not then been established.
[2] Present mountain ranges formed by upheaval.
[3] Ice age.

Palæozoic.	Permian . .	Reptiles first seen. Tree-ferns and conifers.
	Carboniferous .	Amphibians appear. (Labyrinthodon, which disappears in the triassic.)
	Devonian . .	Insects. Cryptogams.
	Silurian . .	Fishes. Annulosæ. Echinodermata. Cæleanterata. } First occur. Seaweeds, mosses and ferns.
	Cambrian .	Molluscs appear.
Archean.	Huronian . .	No definite record of any animal or vegetable life.
	Laurentian.	

At the present day there is a continual change in the earth's surface, due to certain natural agencies :—

1. *Temperature.*

In the tropics, hot sun and cool nights cause much strain to superficial rocks, which thus often split open and peel off.

2. *Saturation and Desiccation.*

Alternate soaking and drying of exposed rocks will rapidly disintegrate many varieties, such as shale.

3. *Frost.*

The expansion of water when freezing soon breaks up rock or soil which contains water in its interstices.

4. *Rain.*

In falling, rain absorbs many gases, such as O, CO_2, etc., and therefore, in addition to its solvent action on

rocks, there will be a chemical action of oxidation, formation of carbonates, etc., which causes much "weathering."

5. *Rivers.*

The decayed surface material is washed off by rain and taken towards the sea by rivers. This removing power takes place at about the rate of one foot in 13,000 years.

Rivers gradually deepen their channels by chemical solution and mechanical friction.

When the erosion has so lowered the slope of the bed that the current can no longer drive along the sediment, it ceases and begins to silt up.

6. *The Sea.*

This agent eats away the shore, by mechanical erosion, at the average rate of 10 feet a century, but of course at a much greater rate in certain positions and with certain strata.

Soils and Subsoils.

On excavating from the surface of the ground to the rock below, we find three distinct layers, representing successive changes in surface decay.

Below is the rock. According to the nature of this rock so will be the nature of the superimposed soil. Clays will produce clay-soil; sandstones will give a sandy soil; sandstone plus clay will give loam, and so on.

Above the rock is the *subsoil*, which is a broken-up, crumbling layer of rock and soil with stray roots descending into it. The disintegration of the rock perpetually proceeds by the percolation of rain-water containing organic acids derived from the vegetation above. This disintegration must continually be proceeding in the rock below or else the upper vegetation

would, in course of time, extract all the nutriment from the soil and then die.

Above the subsoil is the dark band which forms the top layer, or true *soil*, and this represents the most complete surface decay. The plants die in successive generations, gradually darkening the soil.

From the surface of this soil there is an imperceptible removal of material, chiefly by the agency of :—

(*a*) Rain.
(*b*) Wind.
(*c*) Earthworms.

If soil is bare, the rain will wash down the finer particles.

Much sun-dried soil will form dust and be carried off by the wind.

Even when protected by vegetation, rabbits, moles and earthworms throw out a large amount of soil. The latter were estimated by Darwin to throw up 10 tons per annum on each acre.

In addition to the local production of soil and subsoil, rock débris will form "talus-slopes" and "screes" at the foot of cliffs, or a layer of "rain-wash" or "brick-earth" on gentle slopes.

The action of wind may pile up "sand-dunes."

But in none of these accumulations is the condition permanent, for as long as they are exposed to atmospheric influences they are always liable to be swept away by wind, rain and rivers.

The existing scenery of the land is largely due to the eroding action of the various atmospheric agents, continued through long ages.

MINERALOGY.

A *mineral* is an inorganic substance of definite chemical composition and generally of a definite geometrical form.

Some consist of one element only, as the diamond, gold, etc.

The crystalline forms can be reduced to 6 primary types, which are distinguished from each other by the number and position of their axes:—

Systems of Crystals.

I. **Isometric.**

Three axes of the same length, intersecting each other at a right angle.

Examples of this shape are—the cube, the octahedron and the dodecahedron.

These crystals are very symmetrical with length, breadth and thickness equal.

Mineralogical examples are—Common salt, fluor spar and magnetite.

II. **Tetragonal** (Dimetric).

Three axes intersecting at right angles, but the *vertical axis* longer or shorter than the two *lateral axes.*

III. **Orthorhombic** (Trimetric).

Three axes intersecting at right angles, but of unequal lengths.

IV. **Hexagonal.**

The only system with 4 axes. The lateral axes all equal and intersecting at right angles the longer or shorter vertical axis, but forming with each other angles of 60°.

Water and quartz crystallise in this system.

V. **Monoclinic.**

Axes of unequal length, one cutting the vertical axis at right angles and the other, obliquely.

Examples are Hornblende and Gypsum.

VI. **Triclinic.**

The most symmetrical of the systems.

All the axes are unequal and oblique.

Minerals can only crystallise properly if they have space and time; otherwise they will form imperfect crystals.

In addition to crystalline forms of minerals, the following *non-crystalline types* may occur:

a. *Fibrous.*
b. *Concretionary.*
c. *Stalactite.*
d. *Amorphous.*
e. *Vitreous.*

CHIEF MINERALS.

1. **Quartz.** SiO_2 (silica). Sp. gr. 2·65.

This is the most abundant mineral of the earth's crust.

It occurs in crystalline and in non-crystalline form.

Examples are—Amethyst, chalcedony, agate, jasper, opal and flint; and is also a constituent of granites and sandstones.

2. **Hæmatite.** Fe_2O_3. Sp. gr. 5·19.

Occurs in rhombohedral crystals or massive concretions. It is sometimes crystallised in fissures of lavas, but is more common in veins and cavities of concretionary masses and beds.

3. **Limonite.** $2Fe_2O_3, 3H_2O$. Brown Iron Ore.

Is lighter and softer than hæmatite. Is deposited by the action of vegetation in lakes and bogs.

4. **Magnetite.** Ee_3O_4.

Crystallises in isometric octahedrons and dodecahedrons.

Is found abundantly in schists, lavas and other rocks, and also forms massive beds.

It has magnetic properties.

5. **Ilmenite.** $TeTiO_3$. (Titanic iron.)

Occurs in iron-black crystals scattered through many crystalline rocks, such as basalt, etc.

6. **Felspar.** $K_2O,Al_2O_3,6SiO_2$. (Potassic aluminic silicate.)

Constitutes the largest part of the crystalline rocks, and is found abundantly in the schists.

By decomposition it has given rise to the clays.

7. **Mica.** $(MgKFe)_4O,(AlFe)_2O_3,4SiO_2$.

Occurs as an essential of many eruptive and schistose rocks.

Granite is composed of quartz, felspar and mica.

8. **Hornblende.**

Is a magnesium silicate, with calcium and iron oxides.

It is abundant in many eruptive rocks, and may form entire beds amongst the crystalline schists.

9. **Calcite.** $CaCO_3$.

Rhombohedral crystals.

If pure it is transparent, as in "Iceland spar."

Impure, it may form massive beds known as "limestone."

10 **Gypsum.** $CaSO_4,2H_2O$.

Crystallises in right rhomboidal crystals.

It occurs in beds, associated with rock-salt and dolomite.

It may be clear and colourless (selenite), or white and granular (alabaster).

11. **Barytes.** $BaSO_4$. (Heavy spar.)

Orthorhombic tabular prisms.

Associated with metallic ores and diffused in sandstones.

12. **Apatite.** $Ca_3(PO_4)_2$.

Hexagonal crystals abundant in many crystalline rocks; and also occurs as large crystals associated with gneiss in amorphous beds.

It is soluble in water containing CO_2 and some salts, and can thus be introduced into the soil and absorbed by plants.

13. **Fluor Spar.** CaF_2.

Light green or yellow cubes, occurring in mineral veins and often accompanying lead ores.

14. **Halite.** NaCl. (Rock Salt.)

Crystallises in cubes, and formed in massive beds, marking the evaporation of bygone inland seas.

15. **Pyrites.** FeS_2.

Hard, cubical crystals, abundantly diffused in many different rocks.

CLASSIFICATION OF ROCKS.

This is three-fold :—

1. Sedimentary,
2. Eruptive or igneous.
3. Metamorphic or schistose.

I. Sedimentary Rocks.

This division includes the largest number and most accessible of the rocks.

They are not original or primitive rocks, but are derived from some such source as decay of the land, or

the growth of plants, etc., being due to the deposition of sediment or detritus.

They have been deposited layer above layer, in water or air, and are thus usually *stratified.*

According to their origin they are divided into three sections—

(*a*) Fragmentary or clastic.
(*b*) Chemically precipitated.
(*c*) Formed from organic remains.

(a) *Fragmentary or Clastic.*

Breccia.—Rock with angular fragments, showing that it has not travelled far.

Gravel.—Rounded and water-worn detritus ranging in size from a pea to a walnut, and as such known as "*shingle.*" The harder stones, such as quartz and siliceous stones, will, of course, usually form the gravel, as the softer kinds would wear away entirely.

Conglomerate.—This is merely gravel or shingle which has been consolidated into stone, and is named "quartz-conglomerate," etc., according as quartz, flint, limestone, basalt, etc., enter into its composition.

Sand.—This is very fine detritus, either calcareous or siliceous according as it is derived from shells, corals, limestones, or from ordinary sandstone, silica or quartz.

Sandstone.—This is consolidated sand, or small particles of quartz cemented together by clay (argillaceous sandstone); by calcium carbonate (calcareous sandstone); by peroxide of iron (ferruginous sandstone); or by a deposit of silica (siliceous sandstone).

The colours depend on this cementing material.

Greywacke.—A compact grey rock consisting of some quartz particles cemented together, but

containing a much greater percentage of other minerals than in the case of sandstone above.

Clay.—This is an argillaceous matter derived from the hydration of aluminium silicates.

It is usually mixed with impurities which colour it.

The purer forms are known as *kaolin*, from which porcelain is made.

Shale.—This is clay of the older geological formations, which has in course of time been split up into thin parallel laminæ.

Gradations can frequently be traced into other sedimentary rocks.

Loess.—A calcareous clay probably accumulated by wind drift.

Tuff.—This is volcanic dust, consisting of small particles of glass or devitrified crystals which have become consolidated together.

(b) *Chemically precipitated.*

Limestone.—A compact or crystalline calcium carbonate.

Of those formed by chemical means we have—*Stalactite*, *oolite*, and *travertine*.

Dolomite.—Occurs as a crystalline or compact rock, composed of a double carbonate of magnesium and calcium.

It occurs in beds, frequently associated with gypsum and rock salt; it is harder than limestone and less soluble in acid.

Gypsum.—Not only a mineral, but occurs as rock in beds and veins associated often with red clay and rock salt. It has probably been formed by the evaporation of a solution containing it—such as sea-water.

Rock Salt.—Occurs in beds sometimes several thousand feet thick.

(c) *Formed from organic remains.*

Limestone.—This is not only formed by chemical action as above-mentioned, but may largely be formed out of the hard shells, etc., of marine animals. Examples of this kind are—

Shell-marl, which is a fresh-water limestone, formed by the hardening of a white fresh-water shell deposit.

Coral-rock.—A limestone formed by the cementing of corals and coral detritus.

Chalk.—A soft white rock composed of the compressed powdered remains of foraminifera, shells, etc.

Peat.—A brown or black fibrous mass of altered vegetation, occurring in bogs. The lower portions lose their vegetable structure, and get compacted into a kind of black clay.

Coal.—A black stone composed of mineralised vegetation. It is found in beds superimposed on clay, and covered with sandstone, shale, etc.

Flint.—Dark lumps or irregular sheets occurring in chalk or some other limestones, and frequently enclosing sponge spicules, sea-urchins, shells, etc.

It is formed by the abstraction of silica from sea-water by animal remains.

II. **Eruptive or Igneous Rocks.**

These consist of all the massive rocks which have been erupted to the surface from below.

They are chiefly composed of various silicates containing also iron oxide and calcium phosphate.

They can be divided into 3 classes, according to the proportion of silica.

(*a*) Acid rocks.—Silica 66 to 76 % and obvious as free quartz.
(*b*) Intermediate rocks. Silica 56 to 66 %.
(*c*) Basic rocks. Silica below 56 %.

(a) *Acid rocks.*

Granite.—A crystalline rock mostly composed of felspar with scattered quartz, mica and hornblende.

Rhyolite.—Includes the more acid lavas. Some are true glasses (*e. g.* obsidian)

If, when molten, it has been forced up by steam expansion in its interstices, it forms the spongy substance—*Pumice.*

Unvitrified rhyolite consists of sanidin with quartz grains.

(b) *Intermediate Rocks.*

Syenite.—A crystalline rock resembling granite, but without free quartz.

Diorite (Greenstone).—A crystalline aggregate of felspar, hornblende and magnetite, of dark green colour and granitoid texture.

Andesite.—Volcanic rocks of a soda-lime felspar basis, arranged in a "felted" structure. Cavities within are frequently filled with calcite, chalcedony, etc.

(c) *Basic Rocks.*

Basalt.—A coarsely crystalline or vitreous group of rocks, consisting of felspar, magnetite, olivine etc. They are volcanic lavas, often assuming columnar forms.

Peridotites.—Consist chiefly of olivine which has been intruded by volcanoes and not poured out in surface streams.

Serpentine.—A compact mottled rock of greenish red, or purple colour.

It is composed of altered magnesian silicate. Occurs in beds associated with limestones and schists.

III. Metamorphic or Schistose Rocks.

These may originally have been either igneous or sedimentary, but have been altered in structure by heat and pressure.

Clay Slate.—Was originally sea-bottom mud.

Marble.—This is altered limestone, occurring in beds among the schists.

Quartzite.—An altered quartz sandstone.

Occurs in beds associated with slates and limestones.

Mica-schist.—Composed of quartz and mica.

Gneiss.—A schistose aggregate of felspar, quartz and mica, probably derived from the granites.

STRUCTURAL GEOLOGY.

Bosses.

These are masses of rock which have been injected when in a liquid state into rents of the earth's crust, and there solidified.

If at the surface, the surrounding material has been worn away.

Cleavage.

This does not depend on the original structure of the rock, but is a tendency to split into parallel leaves along the planes of re-arranged particles, due to intense subterranean compression which has forced the long axes of the particles in a direction perpendicular to the direction of pressure.

Concretions.

These are a characteristic of many sedimentary rocks, especially clays, limestones and ironstones, and have generally formed round some organic nucleus.

Consolidation.

The materials were, of course, at first only loosely deposited.

They are afterwards consolidated, partly by the pressure of the superimposed layers and partly by the natural, cements, such as silica and calcium carbonate.

Dip.

The inclination of strata to the horizon is called the "dip."

As the deposit was originally horizontal, the dip is due to movements of the earth's crust.

Dislocation.

This is a rupture of continuity of a stratum due to excessive strain, which therefore goes beyond plication, and actually alters the level of the two component surfaces, thus forming a geological "*fault.*"

Joints.

These are natural fissures in the sedimentary rocks, and are due either to torsion or pressure resulting from movements of the earth's crust, or to the internal strain of contraction when drying.

Necks.

These are the filled-up funnels of former volcanoes.

Outcrop.

The exposed edge of a stratum is called its outcrop. Unless on a level surface, strike and outcrop do not coincide.

Overlap.

A thick series of sedimentary deposits indicates a slowly-sinking sea-bottom.

The later deposits will thus spread beyond the limits

of the previous ones, and what is called an "overlap" will result.

Plication or Shearing.

This is the crumpling up of solid strata by compression and distortion, due to crust movements.

Sills, or Intrusive Sheets.

These somewhat resemble bosses in that it is extruded liquid rock. But in this case it has not solidified in a rent, but has forced its way between two sedimentary layers and thus appears as an interstratified bed.

Stratification.

The superimposed layers of sedimentary rocks show a record of various deposits.

The thinnest layers form *laminæ.*

Layers are usually parallel, marking the water-floor at the time of formation. When they are diagonally inclined at various angles, it is known as *false bedding.*

Strike.

This is a line drawn at right angles to the direction of the dip.

Veins and Dykes.

Liquid rock which has been forced up and solidified in vertical fissures is called a "dyke." If it has solidified in irregular rents it is known as a "vein."

They vary in breadth from 1 to 100 feet or more.

CHAPTER XV

SANITARY ARCHITECTURE AND ENGINEERING

Sites for Houses.

The following points should be noted—

a. Fair elevation.
b. Free circulation of air.
c. Shelter from cold winds.
d. Good geological formation (gravel, hard rock, or porous sand is best).
e. Soil should not be a "made" soil.
f. Subsoil water should be at least 12 ft. from surface, and should not show great fluctuations.
g. Good water supply.
h. Gravity conditions suitable for drainage.
i. Southerly or S.W. aspect.
j. Sound foundations.
k. No obnoxious industries in the neighbourhood.

A man requires a house, and, being a gregarious animal, collections of houses are soon formed; hamlets become villages, and villages towns.

In the growth of towns many unhygienic obstacles may have to be overcome, and as the town cannot be moved, considerable engineering projects have to be undertaken.

In the present days of modern sanitary enlightenment, the strictest attention and supervision should be paid

to such urban growth, and this will often obviate much subsequent expense.

The chief points to be observed in urban disposition are—

1. Good water supply.
2. Secure from floods.
3. Sufficient altitude for drainage.
4. Open spaces to be provided at intervals.
5. Streets should be 36 ft. wide.
6. Offensive industries should be regulated.
7. No back-to-back houses should be allowed.

BUILDING MATERIALS.

1. *Cement* (or Hydraulic Mortar) is employed for buildings exposed to the action of water.

It consists of a mixture of calcium carbonate and blue lias clay. This mixture is well powdered and mixed with water, after which it is dried on iron plate. It is then calcined at 200° C. (a greater heat would vitrify the lime and prevent it slaking), ground to powder, and is ready for use.

This powdered cement, when mixed with water, solidifies owing to the formation of hydrated double silicates and aluminates, and forms a very hard material which is unacted on by water.

The rapidity of solidification depends on the quantity of clay present. 25 to 35 % of clay makes *Roman cement* which hardens in a few hours. 10 to 20 % of Medway Valley clay constitutes *Portland cement.*

A good cement is:—

(*a*) Of blue-grey colour.
(*b*) Not gritty to the fingers.
(*c*) Of 110 to 112 lbs. weight per bushel.

2. *Concrete.*—This is a mixture of cement with sand and rubble, which forms blocks of stone-like consistence. The addition of sand and rubble greatly cheapens

the material; and by using shapes, blocks of any required shape can be made. Hollow concrete bricks are coming into use, and are very sound.

The best proportions for concrete are:—

Cement	1.
Sand	2.
Rubble	3.

3. *Mortar.*—Mortar is calcium carbonate, derived from shells, etc. This is calcined, which converts it into the oxide (CaO). Water is added to form slaked lime [or calcium hydroxide, $Ca(OH)_2$].

The composition of the mortar is:—

Slaked lime	1.
Sand	3.

The addition of sand prevents shrinkage and aids in the penetration of the atmospheric CO_2 by which hard calcium carbonate is once more re-formed.

4. *Bricks.*—Most bricks are made of "*clay marl*" (Calc. carb., clay, and iron oxide). This is made into a paste with water, pressed into moulds, dried in the air and then burnt in kilns. Owing to the green vegetable matter with which the fire is damped in clamp-burning, the process is deemed an "offensive trade" under the P. H. Act. CO_2, SO_2, and CO are also evolved during the process.

Bricks may also be made of "*clay loam*," which is a mixture of clay and sand.

Those which are made from "*pure clay*"—aluminium silicate—are used as fire-bricks, since they will stand a high temperature.

Bricks are usually $9'' \times 4\frac{1}{2}'' \times 3''$, should be about 5 lbs. in weight, homogeneous throughout in character and colour, and should not be able to absorb much more than 10 oz. of water.

5. *Wood.*—Many of the N. American houses, especially in out-of-the-way places, are made of wood; and this material is also largely used in the tropics.

The chief woods are:—

Ash, *oak*, *elm*, *pine* (deal), *fir*, *larch*, and *cedar*. Most of these are, however, under favouring circumstances,

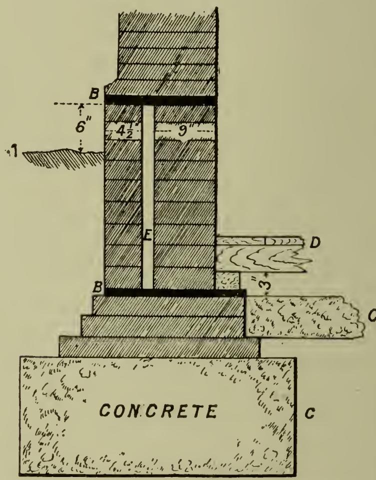

FIG. 43.—DOUBLE DAMP-COURSE.

A, Ground Level. B, B, Damp-courses. C, C, Concrete. D, Floor. E, Cavity between walls.

liable to wet or dry rot and to the attacks of white ants in the tropics.

The only wood which is really suitable for a tropical building is *teak*.

Decay (due to fungi) may often be obviated by treating the timbers with creosote (Bethell's process) under pressure.

It should also be periodically painted or varnished in exposed conditions.

6. *Stone.*—The following stones are most frequently used in buildings:—Sandstone, limestone, granite, marble and slate.

Sandstones may have siliceous or argillaceous (clay) matrices. The well-known Bath-stone is a good example of this stone.

Limestones consist of calcium carbonate, silica and clay. Granite is very suitable for foundations.

7. *Ferro-concrete.*—Iron and concrete having much the same coefficients of expansion, it is possible to make use of concrete with an iron or steel core. The iron is thus protected from the weather, and a fire-proof and water-proof material of great strength is easily obtained.

ARCHITECTURAL DETAILS.

1. *Foundations.*—These should be of concrete, or granite upon concrete; and the whole site should be concreted to a depth of 6 inches to prevent the entry of ground air or water.

Basement cellars should be cemented above the concrete floor, and should be kept as dry as possible.

2. *Walls.*—Heavy or main walls should be broadly based ("footings") on both sides, and rest on secure foundations.

Moisture can rise over 30 ft., by capillary attraction, up the walls of a house; it will therefore be necessary to insert damp-proof courses. The materials used for such damp-proof courses are:—

a. $\frac{3}{4}''$ Asphalt.
b. $1''$ Cement.
c. Glazed stoneware.
d. Slate.

One such layer should be interposed between the footing and the wall.

A second course $6''$ above the external ground-level,

and a third at the top of the wall to prevent the roof moisture descending.

The wall materials are laid in courses, and the space between the stones should not be more than $\frac{1}{8}''$, and between bricks $\frac{1}{4}''$.

They are cemented together with mortar or with cement, and the materials are kept well moistened to prevent too rapid absorption of moisture from the mortar, which would prevent its proper setting.

The stones or bricks are called "*headers*" if their long axis is at right angles to the line of the wall, and "*stretchers*" if their long axis is parallel with the run of the wall.

In heavy walls, stones are laid at intervals, passing right through the wall, for strengthening purposes (bonding stones).

Brick walls are thicker at the base than the top; and, if outside, must in no case be less than 14 in. thick. Party walls not more than 25 ft. high may be $4\frac{1}{2}$ in. thick, and then all the bricks will be laid as "stretchers."

There are three chief types of bonding in brick walls:—

(1) *Old English.*—Alternate courses of all headers and all stretchers.

(2) *Flemish.*—Headers and stretchers alternating in each course.

(3) *Bastard.*—Between header courses two or three courses of stretchers intervene.

Internal walls may be of brick, or of "lathe and plaster." If papered, it should be with a non-poisonous material, and preferably varnished and washable. The best treatment for walls is to paint with some washable "art distemper" which can be obtained in all colours.

3. *Chimneys.*—Chimney-flues should be circular, of as straight a course as possible, smooth-lined, and should rise at least three feet above the roof.

4. *Flooring.*—For basement or ground-floor rooms, concrete, asphalt, marble, tiles, mosaic, or wood-parquetry are the most suitable materials.

FIG. 44.—PLAIN.

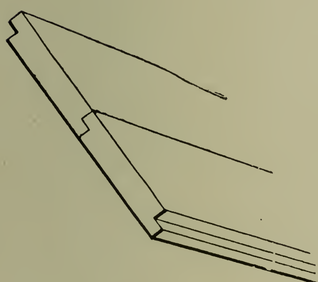

FIG. 45.—REBATED.

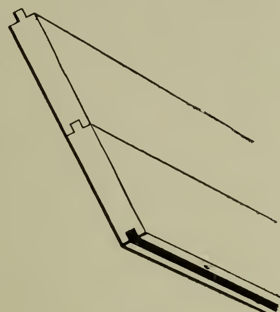

FIG. 46.—GROOVED AND TONGUED.

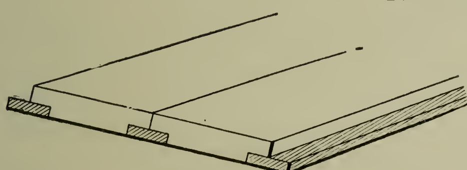

FIG. 47.—FILLETED.

Other floors are wood sheathed on the floor joists. This planking is nailed down, and the joints between the planks may be of different kinds; *e.g.* :—

The space below the floor should not be filled, as is usually done, with plasterer's rubbish. Carded felting may be used to deaden sounds, if necessary, but the

space should always have outside ventilation by "ventilating bricks."

5. *Ceilings.*—These may be either of wood panelling, or of lathe and plaster. The latter should be white-washed at intervals, or better still, papered and varnished.

6. *Windows.*—There should be a window area of 1 sq. ft. to every 100 cub. ft. of room area; and they should be capable of free opening. The minimum of window area should be $\frac{1}{10}$ of the floor space.

7. *Stairs.*—These should preferably be constructed of stone or concrete and should have a "tread" of 9 to 12 in., and a "riser" of not more than 7 in.

8. *Roofs.*—Roofs are covered with various materials.

(a) *Lead.*—Suitable for flat roofs.

(b) *Iron.*—Corrugated iron, kept well painted, is a suitable material for roofing of barns, sheds, etc.

(c) *Slates.*—The roof should not be inclined at less than 25° to the horizon.

The slates should be laid on felt, and are fastened with nails to the rafters.

Each slate overlaps the joint of the two immediately below it, and the lower edge should be at least 3 in. below the upper edge of the next layer but one below it.

(d) *Tiles.*—Earthenware or stone tiles, fastened with oak pins, are frequently used for roofing, and are better than slates, since they keep out the rain while admitting of better ventilation.

(e) *Thatch.*—Thatch roofs are generally condemned as harbouring insects and being inflammable. Fires, however, very seldom occur from this cause, and if the straw thatch be renewed every five years it is not too insanitary, is warm in winter and is cool in summer.

In the tropics thatch roofs renewed every five to seven years are the rule for native houses, and

frequently seen in some places on the houses of Europeans.

In the West Indies the whole leaves of the palmetto are used, the stalk being woven round the rafters. In the East split leaves (attap) are used and sewn together.

(f) *Shingles.*—These are wood tiles, much used in America and the West Indies. If made of suitable wood, properly applied and painted, and renewed when required, they form one of the best of all roof materials for roofing in the tropics.

In the West Indies the wood of the Terminalia latifolia (Broad Leaf) is frequently used for shingling. The best wood is that of the West Indian cedar (Cedrela Odorata).

HOSPITALS.

There are three types of hospitals—

(*a*) General hospitals.
(*b*) Isolation hospitals.
(*c*) Cottage hospitals.

(*a*) General hospitals.

The ideal hospital is a one-storied building. Economy of space, however, is so great a consideration that this is seldom possible. The fewer stories the better.

The following considerations must be borne in mind:—

(*a*) The probable number of patients.
(*b*) The cubic space per patient.
(*c*) The warming arrangements.
(*d*) The lighting arrangements.
(*e*) The nursing arrangements.
(*f*) The arrangements for operations.
(*g*) Mortuary and pathological departments.
(*h*) Laundry and linen store department.
(*i*) Commissariat department.
(*j*) Out-patient department.

General-hospital accommodation should be provided at the rate of one medical, one surgical, and one special bed per 1000 of the population.

In large congested industrial areas this might be insufficient.

A minimun of 90 sq. ft. of floor space should be allowed per bed.

No ward should be less than 15 ft. in height.

The width of a ward should not be less than 24 ft. nor more than 35 ft.

The ventilation of each ward should be independent. Two to four or more Tobin's tubes should be placed in each ward, and one or more Mackinnell's ventilators fixed in the ceiling.

Warming is best effected by hot-water or air pipes fitted inside an ornamental chamber in the centre of the ward, which can also serve as an occasional table. A good plan is to admit outside air through pipes under the floor, which open beneath the hot-water pipes and thus distribute the fresh air ready warmed.

The best material for hospital construction is ferro-concrete.

The wards should be lined with cement, and floored with teak well jointed and paraffined. All angles should be rounded.

The furniture should be reduced to a minimum, and should be made of iron, glazed earthenware, or glass whenever possible.

The kitchen should be on the top of the buildings.

Day wards for convalescents, dining-rooms and exercising grounds should be provided.

Pot-flowers can be advantageously kept in the wards, serving to use up the CO_2 pollution and providing grateful scent and appearance.

(*b*) **Isolation Hospitals.**

Provision should be made for 1 bed per 1000 of the

population, for purposes of treating and isolating infectious disease.

A fairly large site should be obtained, well away (if possible) from crowded residential areas.

The site should be surrounded by a wall 6 to 7 ft. high, and no buildings should be allowed within 40 ft. of this wall.

The blocks for treating infectious disease should be built quite separate from each other.

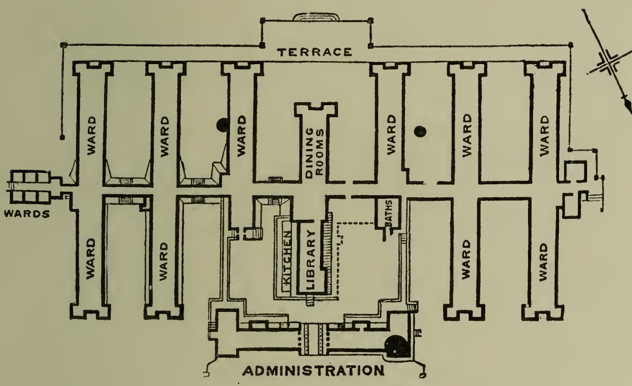

FIG. 48.—PLAN OF THE HERBERT HOSPITAL, WOOLWICH.

The diseases usually requiring isolation, at home, are—

Small-pox, diphtheria, scarlet fever, and occasionally measles.

In the Tropics, it will be small-pox, plague, cholera, yellow fever, epidemic dysentery and (preferably) malaria.

Not more than 20 patients should be treated per each acre of hospital grounds.

The wards should have no woodwork about them.

The floor-space should be 150 sq. ft. per bed, and a

cubic amount of 2500 cub. ft. should be provided for each bed.

One square foot of window should be allowed for each 70 cub. ft. of ward space.

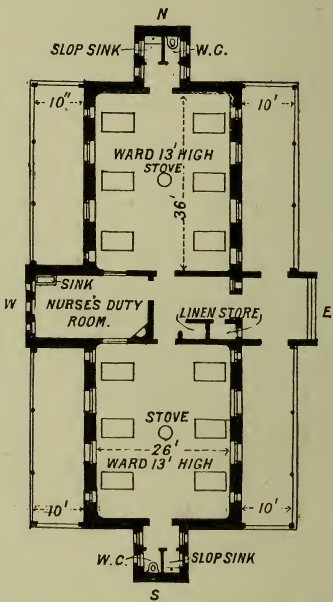

Fig. 49.—Cottage Hospital (12 beds), with Male and Female Wards.

(*c*) Cottage Hospitals.

This provides the sick poor of rural districts with comfortable nursing.

They are maintained by voluntary contributions and by weekly payments of patients.

Admission should be by recommendation of subscribers, and the admission ticket should state the

weekly amount which the patient can afford towards his own expenses.

There should be a matron and at least one capable nurse.

The district practitioners should be honorary medical officers; and either look after their own patients in hospital, or let all the patients be attended by one of the medical men in weekly rotation.

There should not be more than 20 beds.

One bed per 1000 is sufficient provision for most rural districts.

THE A B C OF HOUSE INSPECTION.

Address (and in what municipal or rural district or ward).

By whom occupied and owned.

Closets (? or cesspools). Number. Position. Type. Cleanliness. Ventilation. Number of persons using.

Drainage. Soil pipes. Rain pipes. Waste pipes. Gullies. Traps. Drains and their gradients and distance from main sewer. Ventilation of drains. Soundness as tested by smoke.

Elevation and aspect of house.

Foundations. Area-space. Damp-proof courses. Earth banking. Dryness of basement. Exclusion of ground-air.

General condition.*

Heating, method of. Relation to ventilation.

Inmates. Number of. Age, sex and occupation. Number per room and per tenement.

Juxtaposition of other buildings.

Kitchen premises. Cleanliness. Airiness. Proximity to water-closets. Scullery and grease-traps. Disposition of kitchen refuse.

Live stock. Description. Number. Where kept. Nuisance.

Materials of construction. Foundations, walls, ceilings. Floors. Room walls. Party walls. Roof.
Nature of soil.
Openness of site. Access of light and air. Trees, etc. Area of yard, garden, etc.
Proximity of stables, cowsheds, offensive trades, stagnant water, etc.
Quantity of subsoil water.
Rooms. Number of. Size of. Number of occupants living in. Ditto sleeping in.
Scavenging. Refuse, how stored. Frequency and method of removal. By whom?
Total window-space per floor area and per cubic contents of each room.
Undesirable features.*
Ventilation. How effected. Adequate or inadequate.
Water-supply. Public or private. Constant or intermittent. Springs. Wells. Cisterns.
'**X**istence of possible sources of water pollution.
Yield of water allowed per head.
Zeal (sanitary) of inmates.

DRAINS AND DRAINAGE.

The removal of excreta is a matter which has naturally been of great importance since man began to build urban aggregations of permanent houses.

It is hard to get at historical details, since writers have, as a rule, studiously avoided the subject.

From a passage in Aristophanes (*Ecclesiazusæ*, 1050) we know that the Greeks had some kind of privy in their houses at that period (B.C. 393).

Some such contrivance is probably intended by "the summer chamber" of Eglon, King of Moab of which we read in Judges iii. 20–25.

Under the Romans, sanitation reached a considerable state of excellence. As far as we can find out they

* These items may well be considered last of all.

were the first to use *water-closets.* They had five kinds of receptacles for excreta—

Lasana, or close stools, in which the richer people used gold or silver bowls.

Gastra, or vases, which were put by the roadside for public convenience.

Cloacina, or public privies, of which there were 144 in

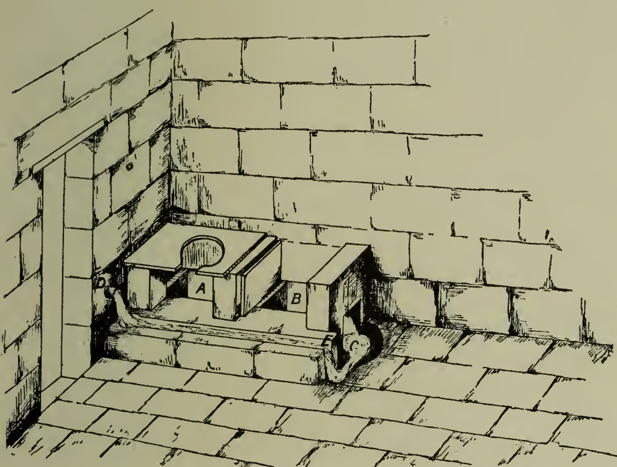

Fig. 50.

Rome. They were connected with a drain and probably flushed at intervals.

Latrina or privies, attached to private houses. The term included the room as well as the receptacle, which was connected with a drain and probably washed out when required.

Sterquilinia or true water-closet. This was in common use in Roman houses of the later period. Examples in excellent preservation have been excavated at Pompeii (*vide* illustration).

It comprised two compartments, one (A) for defæcation and the other (B) a urinal. A constant stream of water flowed in front and then turned round and scoured out the channel under both compartments, washing the contents into a graded drain.

In Constantine's time (A.D. 300), seats in the shape of chairs were used, and had elaborately carved arms and backs.

With the decline of the Roman Empire, water-closets appear to have gone out of fashion, and for nearly a thousand years there seem to have been no privies used inside houses.

Coming to Saxon times, we find privy-cesspools constructed in the walls or turrets of their castles, and the practice was continued by the Normans, who, however, generally built them on corbels from an angle formed by the buttress and the main wall, so that the fæcal matter might conveniently fall down the rocky precipice on which the castle was built.

After the lapse of more than eleven centuries, water-closets were once more revived. The first mention is by Sir John Harrington, of Kelston, near Bath, who invented some such contrivance, and published a poem to celebrate the occasion in 1596. This poem was called the "Metamorphosis of Ajax" (the closed stool or commode in general use in England being at that time called "ajax" or "jakes").

Water-closets are not mentioned again in Europe till 1770. During the intervening period, stools and earth-closets were used.

In Paris, people were allowed to throw their excreta from the windows if they three times gave a verbal warning of "Gare l'eau." The same custom obtained in Edinburgh, and if there were any passers-by they had necessarily to cry, "Haud your han." The practice was forbidden in Paris in 1395, but continued in Edinburgh as late as 1750.

The first English patent for a water-closet was issued in 1775 to Alexander Cumming, a Bond Street watchmaker. This was a valve-closet, and is the first recorded instance of a siphon trap being used.

The next patent was issued in 1777 to a plumber—Samuel Prosser—of St. Martin-in-the-Fields. This was a plunger-closet, with a double ball-cock for shutting off the water when it had reached a certain height, and was the prototype of the pernicious concealed chambers separated from the bowl, but having free communication for the filthy contents.

Modern Closets.

There are two methods in use for the disposal of house sewage: 1, the dry method; 2, the wet method.

Excreta.

Solid excreta per head averages daily	$2\frac{1}{2}$ oz.
Solid excreta per male adult averages daily . . .	4 „
Liquid excreta per head daily .	40 „
N excreted per head daily .	150 grains.
Urea „ „ „ „ .	500 „

Urine and fæces are acid, but soon become alkaline, owing to the formation of ammonium carbonate.

The gaseous products of fæcal decomposition are:—CO_2, H_2S, CH_4, NH_3, N.

I. Dry Methods.

(a) *Earth closets* (Moule's system).—Dry sifted loam or brick-earth is mechanically added each time the closet is used. The excreta are deodorised and organic matter decomposed by chemical and bacterial action.

The earth is subsequently restored to the land, and the system is good for isolated houses in the country.

(b) *Charcoal closets.*—Cheap peat or seaweed charcoal may be used instead of the earth above, using 3 oz. at a time.

It can be re-carbonised in a retort, the carbon being used again and the ammoniacal distillate sold.

(c) *Pail system.*—Covered galvanised buckets or wooden tubs are used. Their capacity should not be more than 2 cub. ft.

The pails are placed under the seat of the closet, and are best removed through a door opening behind the closet. Frequent and regular removal is necessary. The system is used in the country and in the poorer parts of many towns.

The best disposal of the pail contents is secured by burial in shallow trenches, where the nitrifying organisms can deal with it.

(d) *Goux system.*—This is essentially the same as the pail system, but the receptacles are lined with absorbent peat.

(e) *Privy middens.*—This is a closet built over a midden-pit or cesspool.

The midden-pit is generally highly unsavoury and always insanitary. It should be built with impermeable and water-tight walls, such as brick limed with cement.

The capacity should not be more than 8 cub. ft., and it should be cleared out weekly.

The whole should be constructed well away from any house or water supply, and it is better to add sifted ashes, at each service, by some mechanical contrivance.

(Note.—In these dry method systems, the rain and slop water should be removed by gully trap and drains either to (1) surface-soil trenches, (2) subsoil, (3) cesspits, (4) ditches, or (5) streams.)

II. **Wet Methods.**

These consist of various types of water-closet discharging by soil pipe into the house-drain and thence to the public sewer.

W.C.s are best constructed in a turret standing out from the main building, and having an intervening cross-ventilated lobby between it and the house.

Requisites of a good Closet.

(*a*) 3-gall. cistern, 8 ft. above seat.
(*b*) Cistern pipe $1\frac{1}{4}$ to $1\frac{1}{2}$ in.
(*c*) No wooden casing to the seat, which should be hinged.
(*d*) Basin of earthenware.

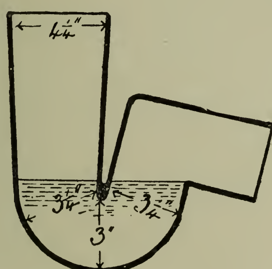

FIG. 51.—FOUR-INCH CAST LEAD ANTI-D TRAP FOR W.C.S.

(*e*) Basin of such size as to be completely scoured.
(*f*) Mechanism to be simple.
(*g*) Flush to be rapid and efficient.
(*h*) Anti-D or syphon trap to be immediately under the basin and above the floor level.
(*i*) All joints to be gas- and water-tight.

Requisites of a good Trap.

(*a*) Should be self-cleansing.
(*b*) Outlet lower than inlet.
(*c*) Water should pass frequently.
(*d*) Seal should be at least $1\frac{1}{2}$ in.
(*e*) Should not be liable to be forced by back pressure of sewer gas.

(*f*) Should be in proportion to size of soil pipe (4 in. trap for 6 in. pipe).

(If too big, will foul; if too small, will syphon dry.)

Types of Closet.

1. *Pan-closets.*—These have a hinged copper "pan"

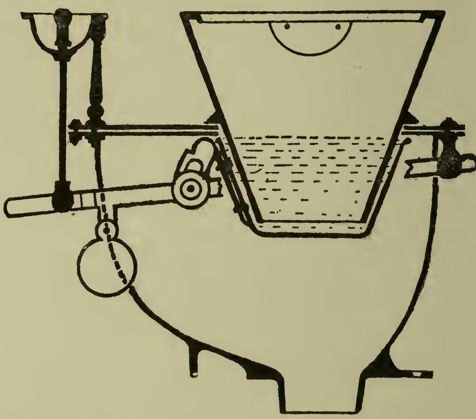

Fig. 52.—Section Pan Closet, showing Basin and Scatterer, Copper Pan, Lever, etc.

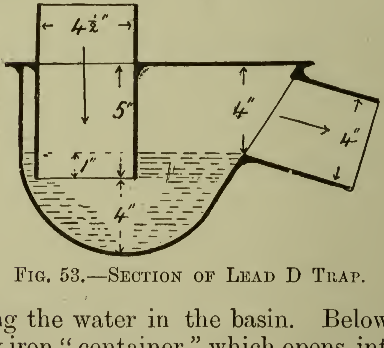

Fig. 53.—Section of Lead D Trap.

for retaining the water in the basin. Below this there is an empty iron "container," which opens into a D trap.

(NOTE.—These are objectionable, and condemned by the model by-laws of the L.G.B.

The pan-mechanism is ungetatable, liable to become foul and get out of order.

The container gets very foul and cannot easily be reached.

The D trap has only a small seal and is not self-cleansing.)

2. *Valve-closets.*—These have a complicated movable valve, and an overflow pipe from above the basin water-line to the neck of the syphon trap.

(NOTE.—This type is objectionable, for the mechanism is apt to get dirty and out of order ; and if the overflow syphons off, then sewer gas can enter the house.)

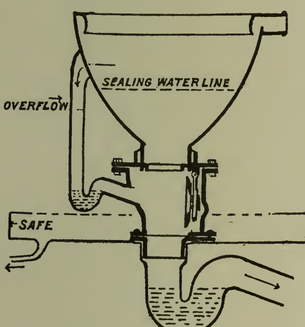

FIG. 54.—VALVE-CLOSET.

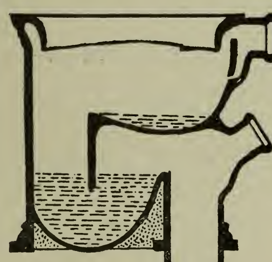

FIG. 55.—SECTION OF WASH-OUT W.C. WITHOUT AFTER-FLUSH.

3. *Wash-out Closets.*

This type, although better than the preceding ones, has some objections.

The lip of the basin is apt to be too high, and thus will prevent the speedy removal of contents.

If too low the water will be too shallow. The inside of the syphon-neck is too much hidden from view.

4. *Long Hopper Wash-down.*

The objection to this type is its height above water-level.

It is hard to scour the basin or to see the trap.

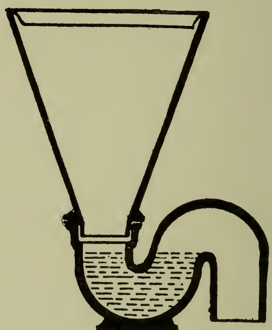

Fig. 56.—Long Hopper Closet.

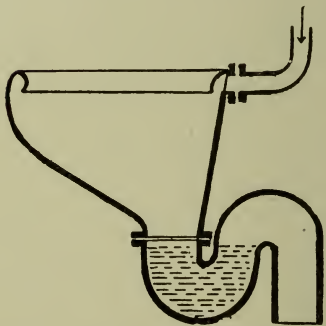

Fig. 57.—Short Hopper Wash-down.

5. *Short Hopper Wash-down.*

This is the best type of w.c. It is cheap. It fulfils the requisites of a good closet. The full force of the scour acts directly on the trap. The fæces do not soil the basin, but fall direct into the trap water.

The annexed cut shows the best form of Short Hopper, the basin having a large water area.

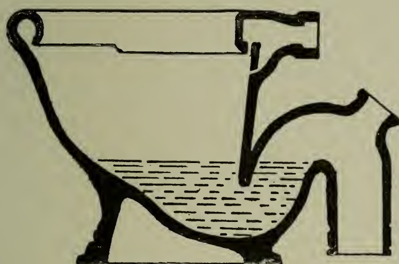

Fig. 58.—Planetas Pedestal Wash-down W.C. with Large Water Area to Pan.

SOIL-PIPES.

The soil-pipes are of iron or lead. If the w.c. trap is of iron, the joint is easy, and consists only of a "caulked" joint. If, however, the closet out-go is earthenware and the soil-pipe of iron, the joint will be a matter of more difficulty, and is probably best effected by rubber washers and screw clamps.

The soil-pipe should not be more than 4″ in diameter, and should run *outside* the house. It should be prolonged full-bore upwards as a ventilating shaft, well above the eaves, and the opening screened.

There should be no trap at the foot of the soil-pipe.

Bends should be avoided.

No rain-pipe must be used as a soil-pipe.

The junction with the house-drain should be curved.

HOUSE-DRAINS.

(*a*) These are of iron or earthenware.
(*b*) They are of 4″ to 9″ in diameter.
(*c*) They should be laid, if possible, in straight lines.

(*d*) They should not go under the house, but if they must, they should be embedded 6″ deep in concrete.

(*e*) Junctions should be made at the side, and preferably in an inspection chamber.

(*f*) Junctions should be curved or oblique.

(*g*) Gradients should be—

4″ pipes	1 in 40
6″ „	1 „ 60
9″ „	1 „ 90

(*h*) On the sewer-side of the house there should be another ventilating shaft for the house-drain.

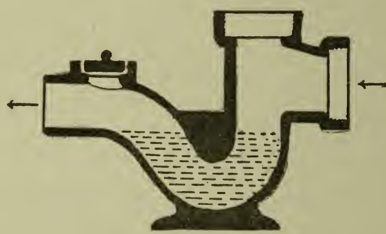

Fig. 59.—Buchan Trap.

(*i*) Beyond this air inlet is the syphon trap guarding the sewer, of which a good type is the "Buchan trap."

WASTE WATER.

Including bath, slop, and rain-water.

Bath waste pipes should be $1\frac{1}{2}''$ to $2''$ in diameter, trapped and ventilated.

Washing waste pipes should be $1''$ to $1\frac{1}{4}''$ in diameter, trapped immediately below the basin.

Both the above should enter into a "main waste pipe"—never into the soil-pipe. This, like the soil-

pipe, should be carried above the eaves for ventilation. Below, the main-waste should open free, in the open air, over a trapped gully.

Scullery waste pipes may also discharge into the main waste pipe, but should be fitted with a "grease trap."

Rain-water, like the "main waste," should open free in the open air over a trapped gully.

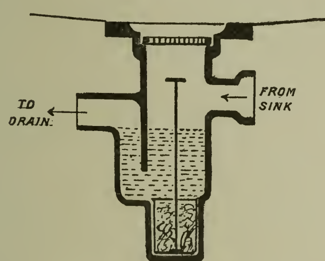

FIG. 60.—DEAN'S GREASE TRAP WITH LIFTING BUCKET.

TESTING OF DRAINS.

All drains should be inspected and tested through their whole length before being covered up.

Smoke test for exposed pipes. Smoke is pumped in from a generator after closing all ventilating openings, and any leaky spots or joints or traps can thus easily be seen.

Peppermint test. Half-an-ounce of crude peppermint oil, with a bucket of boiling water, is poured down the ventilating shaft of the soil-pipe, which is then plugged. Observers are stationed at the various closets and joints.

Hydraulic test. The lower end of the pipe is stopped by an expanding drain-stopper or a rubber bag. The pipe is then filled with water, and any subsidence can be noted.

This test should always be applied to new drains.

MAIN SEWERS.

Sewers are either egg-shaped (for irregular flow) or circular (for uniform flow), and are constructed of cement-lined brick, or of glazed earthenware, or of cast-iron coated with Angus Smith's varnish.

They should be laid on a sound foundation, and at a minimum depth of 5 ft. where there is traffic pressure.

The lighter material should surround it, and the upper 3 ft. should be rammed down.

In a large system of sewers man-holes are required at about every 100 yds., and the sewer should be in a straight line from hole to hole.

Junctions and curves are best made by half-open pipes at the man-hole, and the radius of a sewer curve should not be less than 10 times the sewer diameter.

House-drains should enter obliquely in the direction of the flow, and the entry should be in the upper section of the sewer.

The velocity of the flow will depend on the gradient. It should not be less than 2 ft. per sec., or will quickly foul; nor should it be more than 4 ft. per sec., or it will quickly wear out.

Small sewers require a greater inclination than large ones, and brick drains than pipe sewers.

The sewer gradients should vary from 1 in 244 (15 in. sewer) to 1 in 784 (48 in. sewer).

Non-gravitational removal.

In many places the flatness of the ground makes it impossible to secure proper gradients. In this case there are three chief systems employed—

1. *Shone system.*

The work is done by pneumatic ejectors placed at different stations along the system.

The sewage gravitates into deeply-placed chambers, and, on rising to a certain height, automatically opens a valve admitting compressed air from a central depôt. The sewage is thus forced up a pipe leading to a high level outfall. Automatic valves prevent back-flow into the chamber or house-drain.

The system is in use at Eastbourne, Southampton, Warrington, Cape Town, the Houses of Parliament, and in part of the town at Rangoon.

Generally speaking, it is satisfactory.

2. *Adam's system.*

High-level sewage is used to compress the air in an iron vessel.

This compressed air is then used to force up the low-level sewage, as in the Shone system.

3. *Liernur system.*

Small iron pipes are used, and storm- and rain-waters are excluded.

There is a central pumping station, and sewage is drawn thither by a suction vacuum of half an atmosphere, which will draw air down all the soil-pipes of the system, but does not unseal the w.c. traps.

The system is in use at St. Petersburg, Riga, Leyden, Amsterdam, etc.

If well carried out it is good, but the difficulties are somewhat great.

To Calculate Sewer Discharge.

Owing to air obstruction and friction of the pipes, sewers do not discharge their maximum amount when running full.

We estimate the velocity and discharge as follows—

Let—

V = velocity in ft. per min.

D = hydraulic mean depth.

(*a*) in circ. pipes $D = \frac{\text{Diameter}}{4}$

(*b*) in other pipes $D = \frac{\text{Section area of current}}{\text{wetted perimeter}}$

(*c*) In egg-shaped sewers.

(1) At full bore D = Transv. diam. × ·2897.

(2) At $\frac{2}{3}$ bore D = „ „ × ·3157.

(3) At $\frac{1}{3}$ bore D = „ „ × ·2066.

F = fall in feet per mile.

A = sectional area of fluid current.

Then—

$$V = 55 \times \sqrt{D \times 2F}$$

and discharge (cub. ft. per min.) = V × A.

CHAPTER XVI

DISPOSAL OF WASTE PRODUCTS

In the crowded state of modern industrial centres the disposal of waste products becomes a vital problem. In this chapter the subject will be dealt with under three headings—

1. Disposal of the dead.
2. Disposal of house and trade refuse.
3. Disposal of sewage.

With regard to the latter, the subject of w.c.s, drains, sewers, etc., has already been dealt with in the previous chapters, and only its ultimate disposal is here considered.

I. DISPOSAL OF THE DEAD.

Custom, religion, climate, and convenience have all influenced this subject. The following are the chief methods practised—

1. Earth burial.
2. Cremation.
3. Vault burial.
4. Water burial.
5. Air exposure (for destruction by carrion birds, etc., as amongst the Parsees and some North American Indians).
6. Embalming.

In this matter sentiment and religious prejudice must ultimately be subordinated to the common weal.

In congested districts or towns it is necessary so to dispose of human remains as to ensure—

(*a*) No offence from products of decomposition.
(*b*) No fouling of any water supply.
(*c*) No unnecessary use of valuable land.

To secure this, cremation is undoubtedly the cleanest, quickest, and best method.

In this country vault burial was fairly common until regulations as to the concreting in of each coffin gradually restricted the practice.

At the present day earth burial and cremation are practically the only two methods in use.

1. Cemeteries.

Burial-grounds for a town should be confined to the suburbs.

Old city burial-grounds can with advantage be turned into open spaces and recreation grounds.

The *size* of the cemetery is usually put at $\frac{1}{4}$-*acre per* 1,000 *of the population.*

If the population be over 500,000, the area should be increased to $\frac{1}{2}$-acre.

The *products of decomposition* are CO_2, NH_3, H_2S, and organic compounds. As a rule the air of cemeteries contains more CO_2 and organic matter than other air. It is therefore advisable to plant shrubs, trees, etc., which will keep it dry and use up the CO_2. These, however, should not be too thick to prevent the free play of air over the burial ground.

Heavy wood or lead *coffins* are bad, since decomposition is retarded. Wickerwork or papier-mâché coffins are the most rational.

The use of quicklime will facilitate the destructive processes.

The soil should be finely divided, porous, and dry, and proper drainage should be ensured before the

site is made use of. Loam and sand with vegetable remains, are the best soils; clay and loose stones the worst.

The site should be removed from building land, and not be within 200 yds. of any dwelling-house without consent of the owner.

It should be exposed if possible to N and NE winds.

Ground air and ground water being liable to contamination, special care should be taken with regard to the water supply and cellars in the neighbourhood.

The chief natural agents in the destruction of organic matter put in the soil, are the nitrifying bacteria. These exist in the surface layers, and there are practically none at a depth of 4 or 5 feet. The best method of earth burial would therefore be a wicker-work coffin placed about 4 ft. from the surface. The destruction would be speedy and, as Vivian Poore showed, no offensive emanations would be apparent.

The following are the *Home Secretary's Regulations for Burial Grounds*, under the Burial Acts of 1863.

(1) The burial ground shall be effectually fenced, and if necessary under-drained to such a depth as will prevent water remaining in any grave or vault.

(2) The area to be divided into grave spaces, and so designated by convenient marks: to be also recorded on a plan.

(3) Burial spaces shall be $9' \times 4'$; or for children under 12, they shall be $6' \times 3'$ or $4\frac{1}{2}' \times 4'$.

(4) Register of names and dates to be kept.

(5) No vault burial unless each coffin separately cemented in.

(6) Except in case of one family, only one body to be buried in one grave.

(7) Unwalled graves of adults not to be opened for 14 years, and of children under 12 for 8 years; except to bury another member of same family, when a foot of undisturbed earth must be left above the previous coffin.

If the soil is offensive, it must be immediately replaced.

(8) Coffins of adults must be not less than 4 ft. from the surface.

Of children under 12 not less than 3 ft. from the surface.

Mortuaries.

It is highly advisable that mortuaries should be erected by the Sanitary Authorities, and that their use by the poorer classes should be encouraged.

This would prevent dangers from the presence of human remains in crowded and insanitary surroundings and occasionally prevent the concealment of crime.

The L.G.B. suggestions are:—

1. Buildings should be isolated and unobtrusive.
2. On ground floor, to be reception-chamber, waiting-room, caretaker's quarters and an outhouse.
3. Mortuary chamber to be lofty, well ventilated, well lighted and cool.
4. Floor should be of cement.
5. Tables should be of slate.
6. Walls, ceiling and roof should be frequently whitewashed.
7. Water should be laid on.
8. There should be a separate chamber for infectious disease.
9. Bodies should be received at any hour of the day or night.

2. **Cremation.**

An Act was passed in 1902 giving leave to sanitary authorities to erect crematoria.

This is the best of all methods. No burial space is used. The destruction to ash only occupies a little over an hour. Offensive gases are consumed, thus avoiding any nuisance.

The only objection is the possible covering of crime, which of course would be obviated by care in death certification and registration.

II. DISPOSAL OF HOUSE AND TRADE REFUSE.

In big towns the disposal of civic waste is a serious

problem. Ash-bin refuse averages 250 tons annually for each 1000 inhabitants.

The removal of this house refuse is carried out in most towns weekly, but in a few places removal twice or thrice is provided for. A daily removal would be the ideal.

The following is the copy of a notice issued to householders by a S.A.

URBAN SANITARY AUTHORITY.

NOTICE AS TO THE COLLECTION OF ASHES AND HOUSE REFUSE.

Men with Horses and Carts are employed by this Authority to collect the Ashes and House Refuse throughout the City, and they have orders to go into every Street for that purpose regularly once a Week, on a certain Day of the Week; they are to ring a bell to make their presence known, and call at every House; and, when requested, to enter the House and take away the Refuse from the receptacle in which it may be deposited. When any such receptacle is placed by the Occupier outside the House the Men, after emptying the receptacle, are to replace it in the house in its usual place.

The day and time appointed for the Men to call may be known by application at the Surveyor's Office, where all Complaints should be sent.

Each Cart has a Number painted on the front of it, and any incivility or inattention on the part of the Men should be reported to the *Surveyor;* complaints to be made in writing, stating the number of the cart which the Man is using.

The Men have orders to collect dust, Cinders, Ashes, and House Refuse only, and are NOT allowed to remove the Refuse of TRADE, as Builder's Rubbish, Broken Bottles from Wine Merchants, Shells and Offal from Fish or Greengrocers' Shops, Straw, Waste Packing, or the like, unless under special arrangements, which may be entered into for the periodical removal of Trade Refuse.

By Order,

City Surveyor's Office. Surveyor.

The collecting carts should be covered. Ash-buckets

should not be put out in the street, where they will chiefly minister to rag-pickers and starving mongrels.

In the poorer parts of a town fixed receptacles should be provided, which can be regularly emptied.

The streets should be scavenged daily.

Trade waste is removed at intervals by special contract.

All this refuse has to be got rid of and this is effected by one of 4 methods—

(*a*) *Filling up waste ground.*

This is a pernicious practice. Putrefying organic matter will cause a nuisance.

The land so formed should not be used for 5 years for building purposes.

(*b*) *Discharge by lighter into the deep sea.*

This is unsatisfactory.

The weather may hinder it.

It is expensive.

Fishing grounds may be ruined.

(*c*) *Employment as manure.*

The carriage is expensive. The refuse has to be sorted at a depôt. The cinders and coal, etc., are sold to brickmakers as "breeze"; broken crockery, etc., known as "hard core," is used for road-making.

Iron, tins, bottles, etc., are separated and sold.

The "soft core," consisting of animal and vegetable refuse forms the manure, which is not a particularly good one. The whole process is too expensive and too insanitary.

(*d*) *Furnace destruction.*

This is the most satisfactory of the methods.

Combustible substances are thus destroyed, and the hard residuum (clinkers) can be used for road-making,

or mixed with lime for cement. Steam can be generated by the combustion, and this can be used for electric lighting, sewage pumping, etc.

With modern destructors 1·43 lbs. of water can be evaporated per lb. of refuse burnt.

Destructors are of two types.

(a) *Natural-draught, slow-combustion furnaces.*

These are represented by furnaces of the "Fryer" type, being a series of cells back to back. Each cell has a sloping hearth and fire-grate, with a top-feeding chamber.

In these the wear and tear is small, but the process is slow, and though the cost is less, yet less economic use can be made of the combustion processes.

(b) *Forced-draught, high-temperature furnaces.*

Of these the "Horsfall" destructor is a good type.

The draught is provided by fans or steam-jet blowers, and a temperature of 2000° F. can be attained, with an average of 1600° F.

The fumes are automatically destroyed, and the furnace has a fine steam-raising power. About two-thirds of the refuse is consumed as fuel and one-third remains as clinker.

The disadvantage of a bad destructor is the production of dust and of offensive vapours and smoke.

The only disadvantage of a good destructor is the dust produced (mineral matter 93·6 %, organic matter 6·2 %), which is rather hard to obviate.

In the "Meldrum" type there is a continuous grate with four sets of firing doors. The fires are clinkered from each door in rotation, and three fires are always kept charged. The products of combustion have to pass over the whole range of fires, and from the combustion chamber they go through a Lancashire boiler in the main flue.

The *average cost* of burning refuse in these forced-draught destructors comes to about 1*s.* 8*d.* a ton in urban and 1*s.* in rural districts.

Continuous feeding is essential for proper working.

III. DISPOSAL OF SEWAGE.

(For drainage and removal of sewage, see Chapter XVI.)

The term "sewage" includes both solid and liquid human excreta, household slop-water, surface rain water, and whatever else is carried off by the drain system of any town.

The total quantity will depend—

(*a*) on the number of inhabitants,
(*b*) on the amount of water supplied per head per day.

Having removed this sewage, the question of its disposal remains. This is usually effected by one of six methods:

1. Sea discharge.
2. Subsidence and precipitation.
3. Electrolysis.
4. Filtration.
5. Irrigation.
6. Bacteriolysis.

It should be noted that, by the Rivers Pollution Acts of 1876 and 1890, no crude sewage may be admitted to any river or stream; and, further, no scheme of discharge of any sewage effluent into a river or stream will be sanctioned by the Local Government Board unless the filtration of such effluent through land has been provided for.

1. Sea discharge.

Crude sewage may be discharged into the sea; an arm of the sea, or tidal estuary, may, however, be

defined by the L.G.B. as a stream, when, of course, this will not be permitted.

It should not be employed unless the sewage can reach the outfalls within six hours.

It should be carried well out to sea in iron pipes which should extend beyond the low-water mark of the lowest neap tide.

To prevent fouling the tidal foreshore the following points must first be inquired into:—

(*a*) Shape of coast line.
(*b*) Nature of tides.
(*c*) Prevailing currents.
(*d*) Prevailing winds.

2. **Precipitation.**

This is the chemical treatment, and the object of the process is to obtain a solid residue and a liquid effluent.

As a practical precipitant the substance should—

(*a*) be cheap,
(*b*) be easily obtainable,
(*c*) act rapidly,
(*d*) produce little sludge and much effluent,
(*e*) not be injurious to workmen,
(*f*) not leave an alkaline effluent.

Precipitation should be effected in 4 ft. tanks arranged in series. The precipitant should be added hot and well mixed.

The following are the chief precipitation processes:—

1. *Lime and Iron Sulphate.*

(As used in London.)

Lime, 4 grs.; iron sulphate, 1 gr. per gall. of sewage.

If too much lime, putrefaction rapidly occurs in the alkaline liquid. The iron delays but does not prevent this.

The process acts mainly on the suspended matter, and the effluent may be offensive.

2. *Lime.*

(As used at Birmingham.)

Slaked lime is made into a cream and added in the proportion of 12 to 15 grs. per gallon.

It is not a satisfactory process, and the effluent is alkaline.

3. *Lime and Alum.*

(As used at Glasgow.)

The sewage is mixed with lime (as in No. 2) and then a solution of alum is added. The result is a large precipitate of aluminium hydroxide.

4. *Lime and Clay.* (Scott's process.)

The clay enables a cement to be made from the sludge (two tons per million gallons sewage).

The process is not satisfactory.

5. *Lime and Black Ash Waste.*

(As used at Aldershot.)

The Black Ash Waste is the waste product from soap works.

It produces calcium sulphite and hyposulphite.

6. *The A.B.C. process.*

So called from the ingredients—alum, blood, and charcoal. The blood is now omitted, being found to be useless.

The actual ingredients used at present are: *alum*, *charcoal*, *zinc sulphate* (refuse from potassium cyanide works), and *lime*. About 67 grs. of a mixture of these ingredients ($ZnSO_4$1 ; CaO5 ; $Al_2(SO_4)_3$21 ; C21) is used for each gallon of sewage.

The bulky aluminium hydroxide and lime carry down all the suspended matters, and the charcoal deodorises.

The effluent is pure, and the sludge contains much P_2O_5 and NH_3, and when dried forms a valuable manure (native guano).

3. Electrolysis.

The sewage flows through tanks containing longitudinal iron plates which are connected to a dynamo circuit.

The current decomposes the water and chlorides. Cl and O are given off at the positive pole and combine with the Fe. This in turn combines with the sewage to form ferrous carbonates and oxides.

Both micro-organisms and the bulk of the sludge are reduced.

The organic matter is extensively oxidised.

The effluent is fairly pure.

4. Filtration.

Filtration through various media has frequently been tried and adopted.

The best medium to use is soil, and the process is then called *intermittent downward filtration.* The process is a four-fold one—

a. There is a mechanical filtration.

b. There is a bacterial action caused by the nitrifying germs in the soil.

c. There is an oxidation by the ground air.

d. There is a chemical effect produced by vegetable growth.

For the process, sand, chalk and clay soils are not suitable. It should be a loam or loose marl.

Effluent drains are placed 10 to 30 ft. apart, at a depth of 6 ft.

Sloping land is best.

The sewage is run in furrows 2 ft. deep, and vegetation can be grown on the ridges.

The area should be so divided by sluices that each portion can have 18 hrs. rest out of the 24 hrs.

Half an acre of ground is the amount required per 1000 of the population if a preliminary subsidence is allowed.

The system is adopted in a good many places.

The effluent contains unchanged chlorides, nitrates and nitrites.

5. **Broad Irrigation.**

This system is merely the distribution of sewage over agricultural land.

If the land is not very permeable, it must be underdrained to the nearest watercourse.

The sewer water should be admitted to this *sewage farm* at the rate of about 8 ft. per hour.

"Arrosage" is the distribution by furrows.

"Colmatage" is the submergence of the surface.

One acre will only do for 100 persons.

Italian rye grass, osiers and mangold-wurzels can be successfully grown, and cattle can with safety graze.

6. **Bacteriolysis.**

The *advantages* of this method over chemical methods are (Clowes)—

a. It requires no chemicals.
b. It produces a sweet vegetable deposit instead of an offensive sludge.
c. It removes the *whole* of the suspended matter.
d. It removes over 50 % of the dissolved putrescible matter.
e. The effluent is odourless and non-toxic to fish.

The *chemical changes produced* by the bacteria are (Lewis & Balfour)—

a. The conversion of urea and other nitrogenous matter into NH_3, CO_2 and water.

b. Oxidation of the NH_3 into nitrites, and nitrites into nitrates (by the nitrifying bacteria of the soil and of sewage).

c. The reduction of nitrates into nitrites, thus liberating O, which oxidises organic matter and reforms nitrates (this is, by the denitrifying bacteria).

d. The conversion of non-nitrogenous matter into CO_2 and water.

e. The conversion of cellulose into CH_4, CO_2, etc. (by *B. butyricus*, *B. gummis* and *B. putredinis*, etc.).

Bacteriolysis is of two types—

1. Aerobic.
2. Anaerobic (*e.g.* Septic Tanks).

1. *Aerobic bacteriolysis.*

Filter beds are made of 4 to 12 ft. deep. Loose-jointed stoneware pipes communicate with the bottom to collect the effluent. A layer of sand covers these pipes. Above this, the main part of the filter-bed is made of coke broken into pieces about the size of a walnut (pan breeze).

At the top is another layer of sand.

The sewage is first screened to separate the grosser solids. It is then distributed by automatic sprinklers over the filter bed.

After about 4 weeks the coke becomes covered with a bacterial slime, and the action then becomes efficient.

In order to secure proper aeration, one filter bed is only allowed to be saturated for 6 hours out of the 24, and is also given an absolute rest of 1 week in 6.

The effluent should be automatically syphoned into a second filter and there collected before being run away.

2. *Anaerobic bacteriolysis.*

This is the principle of the *septic tank.*

An impermeable chamber is made of stone faced with cement, 6 or more feet deep, from which light and air are excluded. This must be large enough to contain a maximum day's sewage plus the estimated storm water, and forms the septic tank proper.

First of all the sewage enters a detritus chamber, the bottom of which is about 3 feet above the level of the bottom of the septic tank.

From the bottom of this detritus chamber there is an opening into the septic tank. This opening being several feet below the level of the surface of the sewage in the tank, it will consequently neither carry air into the tank, nor disturb the scum.

The effluent is allowed to flow slowly through a longitudinal slot about 15 inches below the water level, whence it runs into and over the sides of an open trough (to oxidise) into two receptacles, from which it is distributed on aerobic filter-beds of clinker and gravel, and should be then almost as pure as an ordinary water.

Analysis should give in parts per 100,000—

	O absorbed in 4 hours.	Free NH_3.	Album. NH_3.
Crude sewage . . .	2·85	5·7	0·28
Good effluent . . .	0·57	2·43	0·114

CHAPTER XVII

EPIDEMIOLOGY AND ENDEMIOLOGY

THE principles of bacteriology have already been considered in Chapter XI.

We propose now to consider *seriatim* a *résumé* of the chief infectious, or contagious diseases which are of special importance to the sanitarian.

With a few important exceptions, tropical diseases are not touched on. Notes will be found, however, on the grave endemic and epidemic world-scourges—malaria, plague, cholera and yellow fever.

Infection can only be *contracted* in one of three ways—

(a) *Inoculation.*
(b) *Respiration.*
(c) *Ingestion.*

(*a*) **Inoculation.**—By this term we include the passage of a specific animal or vegetable germ through the skin. Such passage may be accomplished by specific contamination of a skin abrasion, or by the bite of an insect such as a mosquito, bug, flea, tick, etc.

Examples of diseases so carried are: Anthrax, Erysipelas, Hydrophobia, Malaria, Plague, Relapsing-fever, Yellow-fever.

(*b*) **Respiration.**—That is, the infection of a person by inspiring the specific organism.

Examples of such diseases are: Chicken-pox,

German-measles, Influenza, Measles, Mumps, Plague (pneumonic), Scarlet-fever, Tuberculosis, Whooping Cough.

(*c*) **Ingestion.**—That is, infection by the ingestion of the specific organism by food, water, etc.

Examples of such mode of transmission are: Cholera, Diphtheria, Dysentery, Enteric-fever, Plague (septicæmic), Scarlet-fever, Tuberculosis.

The **Notification of Infectious Disease** is of the utmost importance.

By **The Infectious Diseases Notification Act, 1889,** the following diseases are *compulsorily* notifiable throughout England and Wales, including London—

Small Pox.
Cholera.
Diphtheria.
Membranous Croup.
Erysipelas.
Scarlet-fever.
Typhus-fever.
Enteric-fever.
Continued-fever (?).
Relapsing-fever.
Puerperal-fever.
Plague.

Under a default penalty of 40*s.* the medical practitioner must notify any of the above diseases to the M.O.H. at once, stating name, location and disease. For each certificate in his private practice the medico is entitled to a fee of 2*s.* 6*d.*, or 1*s.* in public practice.

If there is no medical man in attendance the head of the family, relative or occupier must inform the M.O.H. under the same default penalty, but with no fee attached.

The act applies to ships, boats, tents, vans, sheds, etc., used as human habitations.

The **Infectious Diseases Prevention Act, 1890,** is *adoptive* by any extra-Metropolitan Sanitary Authority.

Its chief provisions are—

1. *Milk Supplies.*

M.O.H., under Justices' order and accompanied by veterinary surgeon, may inspect both dairies and animals.

If the M.O.H. thinks the milk is carrying infection, the dairyman is given 24 hours' notice by the S.A. to appear and show cause why the supply should not be stopped.

2. *Disinfection.*

On certificate of M.O.H. or any medical practitioner the S.A. may order the disinfection of any house by the owner or occupier after 24 hours' notice.

If this is not done in specified time, the S.A. may do it and recover expenses.

There are powers of entry between 10 a.m. and 6 p.m.

The S.A. may require, by notice, that infected clothing, bedding, etc., be delivered to them for gratis disinfection, with compensation for unnecessary damage.

3. *Prompt Burial.*

Infectious corpses must not be kept more than 48 hours in any place liable to injure the health of the inhabitants.

In a hospital, such body may only be removed for burial.

Infected dead may not be conveyed in any public conveyance except a hearse, without due warning to the driver or owner.

4. *Detention in Hospital.*

If an infectious case has himself gone to, or been

removed to an isolation hospital, he may, by J.P.'s order, be *compelled* to remain there, *at the cost of the S.A.*, if he would not otherwise be provided with domicile suitable to prevent the spread of the disease.

The *Metropolis* is served by the **Public Health (London) Act, 1891.** This comprises most of the provisions of the two Acts above mentioned, with the following chief differences—

1. All London is under the Metropolitan Asylums Board (M.A.B.).
2. The M.A.B. have to send weekly returns of infectious disease to the County Council.
3. Powers for "Epidemic regulations" may be given by the L.G.B. to the L.C.C.
4. M.O.H. after receiving notice of infectious disease must send copy within 12 hours to the M.A.B. and head teacher of school (if a scholar).
5. M.A.B. must furnish all M.O.H.s with weekly lists of all infectious disease.
6. Additional dangerous infectious diseases may be added by any S.A. (with consent of L.G.B.) to the list of notifiable diseases.
7. Every S.A. *must* provide disinfecting apparatus.

The following are important **regulations for preventing the spread of cholera, plague, etc.**

They are made under Sec. 130 of the P.H.A., 1875, and Sec. 2 of the P.H.A., 1889.

1. A quarantine anchorage must be appointed by every port S.A.

2. Provision must be made by them for both infected and suspected patients.

3. If a Customs officer finds a ship infected, he must detain ship, send it to quarantine anchorage, and give notice to S.A.

4. Infected ships must hoist letter "Q" when within three miles of the coast of England or Wales.

5. In the above cases the M.O.H. must forthwith visit and examine ship, and all persons on board.

6. All infected persons must be removed to hospital as directed by M.O.H.

7. If they cannot be removed the ship remains under the control of the M.O.H.

8. Suspected persons are detained for examination, and must not leave ship until after such examination.

9. Those allowed to land must give to M.O.H. name and address and destination, which are forwarded to the S.A. by the M.O.H.

10. Infectious corpses must either be buried at sea or delivered to the S.A., as may be directed.

11. Cholera-soiled articles to be destroyed. Clothing, bedding, etc., to be disinfected and, if necessary, destroyed.

12. Ship to be disinfected at cost of owner, and to satisfaction of M.O.H.

13. If ship is clean, but comes from an infected port or has filthy people on board, M.O.H. may prevent landing until names and addresses have been given, and disinfecting precautions taken. Certificates to this effect must be made out in duplicate for Master and S.A.

14. Bilge-water must be pumped out, and casks and tanks emptied and cleaned before infected ship enters dock or basin.

15. L.G.B. may alter, make or revoke any regulations (if formidable epidemic or infectious disease is threatened or is present) for—

a. Speedy interment of dead.
b. House to house visitation.
c. Provision of medical aid and accommodation.
d. Prevention of spread, whether on land or sea (within the 3-mile limit).

Such are the chief enactments which deal with epidemiology and endemiology.

It remains now to consider the diseases *seriatim*, and for convenience of reference they will be taken in alphabetical order—

I. ANTHRAX.

Synonyms.

Woolsorter's disease ; splenic fever; charbon.

Geographical Distribution.

It is endemic in Catalonia and Romagna, and frequently occurs in Hungary, Poland, France.

Etiology.

The *Bacillus anthracis*, a very large, square-ended bacillus. Liquefies gelatin. Stained by Gram.

Occurs in local lesion and in blood of infected cases.

Resembles *B. mycoides* of the soil, but latter is motile and does not stain with Gram.

Symptoms.

It is primarily a disease of oxen, sheep, horses and pigs. In human beings the incubation period is 48 hours.

The usual type is known as "Malignant Pustule," which follows an accidental inoculation. A local papule is the first symptom. Extensive inflammatory induration follows, and soon, also, constitutional symptoms such as pyrexia, delirium and collapse.

Death usually occurs in 5 to 8 days. Intestinal and pulmonary types are known.

Transmission.

Usually by infected hides and fleeces. Those from Armenia, the Caspian, and S. America are often suspicious. The spores are to blame in the intestinal and pulmonary types.

Prevention.

Animal quarantine against infected places. Destruction of infected animals.

In man early excision of the pustule should be practised.

All cases must be reported to the Home Office, by practitioners, under Factory and Workshops Act, 1901.

II. CEREBRO-SPINAL MENINGITIS.

Synonym.

Cerebro-spinal fever.

Geographical Distribution.

Occurs epidemically and sporadically in Europe, U.S.A., Egypt, Ashanti and India.

Etiology.

The *Diplococcus intracellularis* of Weichselbaum. Found in cerebral and spinal exudation. Small round diplococci, non-liquefying and decolorised by Gram.

Symptoms.

Incubation period is 2 to 7 days.

Sudden invasion with headache, vomiting, fever, rigidity of

the neck and a polymorphous eruption. Death occurs usually within 14 days in fatal cases. Mortality is about 40 %.

It is most prevalent in the winter and spring in cold climates.

Transmission.

Probably aërial from breath and nasal secretions.

Prevention.

Quarantine period 9 days. Cases should be isolated for 14 days after recovery.

III. CHICKEN-POX.

Synonym.

Varicella.

Geographical Distribution.

Most common in temperate and sub-tropical regions, but is also very frequently met with in the tropics.

Etiology.

No specific organism has been established. Disease unknown in lower animals.

Symptoms.

The incubation period is 10 to 16 days. The disease is usually most mild.

A vesicular eruption occurs on the first day of the fever, beginning on the back and shoulders or chest. Many of the vesicles are oval, and when pricked they collapse. If they are circular they are hemispherical and dome-shaped. They are fully developed in one day, and will continue coming out in crops for several days.

In temperate climates the disease is most common in the autumn and amongst children of 3 and 4.

In the tropics it occurs equally at all times of the year and amongst young adults.

Transmission.

Probably aërial.

Prevention.

Isolation of cases.

Infection ceases when all the scabs are gone.

Quarantine from time of last exposure should be 20 days.

IV. CHOLERA.

Synonyms (*Cholera asiatica ; Cholera epidemica*).

Geographical Distribution.

India is the endemic habitat. Pandemics have occurred on many occasions, including seven European invasions during the 19th century.

Australia, New Zealand, and many islands of the Pacific and Atlantic have never been visited by this member of the 4 tropical scourges.

Etiology.

The *Comma bacillus* discovered by Koch in Egypt in 1883.

Curved motile organisms $1\frac{1}{2}$ to 2 μ in length. Liquefaction occurs after 48 hrs.

They are decolorised by Gram. Drying kills in 2 or 3 minutes.

The *cholera red* diagnostic reaction is :—A 24-hours' broth cultivation to which a few drops of H_2SO_4 are added turns pink, due to the fact that the spirillum forms "indol" and a "nitrite," which, in the presence of H_2SO_4, form a red-coloured nitroso-indol body.

(The B.C.C. forms indol but not nitrite. Finkler Prior forms both, but not within 24 hours.)

Symptoms.

The incubation period is about 12 hours.

The onset is very sudden with vomiting and diarrhœa. In an hour or two the symptoms become aggravated with "rice-water," stools, incessant vomiting, and agonising cramps.

The face is pinched and anxious, with eyes deep sunken in the head. The fingers and toes are blue and shrivelled, the voice whispering and husky. There is complete suppression of urine. The radial pulse is imperceptible.

Such is the algide or collapse stage, which terminates in death in 40 to 90 % of cases, according to the virulence of an epidemic.

In favourable cases the symptoms gradually abate, and convalescence is begun in a day or two.

Transmission.

It is water- or food-borne only. Flies are frequent carriers of the germ.

Prevention.

Cases should be promptly isolated and excreta disinfected. All water supply should be looked into promptly. Unripe fruit destroyed.

Infection ceases after the stools have been quite normal for two or three days.

The quarantine against contacts should be seven days after the last exposure to infection.

V. DIPHTHERIA.

Geographical Distribution.

Most prevalent in cold and temperate climates, but may occur almost anywhere.

Etiology.

The *B. diphtheriæ* of Klebs-Löffler.

It is often "clubbed" at one end. It is non-liquefying, and stained by Gram.

Symptoms.

The incubation is 2 to 7 days.

The onset is rapid, with malaise, headache, fever, pain in the throat, and difficulty in swallowing. The glands are frequently enlarged.

After a few hours to days patches of grey membrane appear on the back of the pharynx, the tonsils, or soft palate, and spread, thus gradually coalescing.

The membrane is composed of necrotic *débris.*

Any of the other mucous membranes may be invaded.

An acute toxemia results, giving rise to characteristic paralysis. The disease is most common in autumn and winter, and at the age of 3 to 12.

The mortality is 15 to 20 %.

Transmission.

The disease is usually transmitted either aërially or by infected milk.

Prevention.

Isolation of sick. Notification. Children from an infected house should be kept from school.

Infection ceases 3 weeks after symptoms have ceased. Quarantine against contacts should be 10 days.

VI. DYSENTERY.

Geographical Distribution.

May occur in all latitudes. The sporadic and epidemic types occur anywhere. The endemic type is tropical.

Etiology.

There are three different kinds of dysentery:—

1. *Sporadic dysentery.*—Due to mechanical irritation, *Paramœcium coli*, *B. coli communis*, or other causes.

2. *Endemic dysentery.*—Due to an amœba—the *Entamœba dysenteriæ*. These are associated but non-pathogenic organisms such as *Entamœba coli*, *Paramœba hominis*, *S. pyogenes aureus*.

3. *Epidemic dysentery.*—Due usually to the *B. dysenteriæ* (Shiga-Kruse); also, more rarely, to one of the para-dysentery bacilli, *e.g.* Lenz, Flexner-Strong, or Harris-Gay.

Symptoms.

Frequent stools containing blood and mucus. Griping and tenesmus. The latter is most urgent if the lesions are near the rectum; if near the cæcum, griping.

The *epidemic type* (with which the European Sanitarian is chiefly concerned) is associated with fever. Relapses are rare. Ipecacuanha is useless. Liver abscess does not occur.

Transmission.

Usually water-borne.

Prevention.

Isolation of cases. Disinfection of stools. Care for water supply.

VII. ENTERIC FEVER.

Synonym.

Typhoid fever.

Geographical Distribution.

World-wide—in epidemic or endemic form.

Etiology.

B. typhosus (Eberth).

A short, oval-ended and very mobile rod. Does not liquefy gelatin and is decolorised by Gram.

It has considerable resemblance to the *B. coli communis*, but the latter forms gas in stab cultures, which the *B. typhosus* does not.

Symptoms.

The incubation is 12 to 14 days. The onset is insidious. The temperature slowly mounts for about a week, remains up for a couple of weeks, and then abates by slow lysis. There is ulceration of Peyer's Patches, enlargement of the spleen, a rose-red rash on the abdomen, and usually diarrhœa, resembling pea-soup.

Perforation may lead to fatal hæmorrhage or peritonitis.

The disease usually occurs in the autumn, and amongst young adults.

The mortality is about 15 %.

Transmission.

Usually water-borne.

Prevention.

Isolation of cases and disinfection of excreta.

Careful attention to water supply, dairies, oyster-beds, etc.

Infection lasts till the discharges are free from specific germ.

VIII. ERYSIPELAS.

Geographical Distribution.

World-wide, but especially in temperate climates.

Etiology.

The *Streptococcus erysipelatis* (Fehleisen).
Gelatin is not liquefied, and it is stained by Gram.

Symptoms.

There is an incubation period of 1 to 7 days.

There is a sudden onset with fever, a spreading sharp-edged rash, and frequently a rigor.

It is common in connection with wounds.

It is most prevalent in spring and amongst the young.

Transmission.

The disease may be contracted through wounds or be spread aërially.

Prevention.

Isolation of the sick. Notification.
Care in surgical wards or midwifery practice.

IX. GERMAN MEASLES.

Synonyms.

Rubeola ; Rubella ; Röthelu.

Geographical Distribution.

Its chief prevalence is in northern temperate climates. It also occurs in Egypt, India, China and other places.

Etiology.

The specific organism is as yet undiscovered.

Symptoms.

There is an incubation period of 9 to 21 days (usually 18). It occurs in epidemic, and has an eruption like that of measles, the other symptoms more resembling scarlet fever.

There is a mild fever lasting two or three days with a dry throat, and some ordinary catarrhal symptoms. On the second day dusky red papules occur, beginning behind the ears, round the mouth and on the scalp, and then extending to the rest of the body. The laryngeal symptoms become aggravated.

The rash lasts 5 days, and is followed by slight desquamation. It is most prevalent in spring and summer, and between the ages of 5 and 15.

Transmission.

Probably always aërial.

Prevention.

Isolation of sick and notification. Infection ceases about 21 days after onset.

Quarantine against contacts should be 23 days.

X. HYDROPHOBIA.

Synonym.

Rabies.

Geographical Distribution.

Occurs in most parts of the world, but has been stamped out in Sweden, and has never been found in Australia.

Etiology.

The virus exists in the saliva and spinal cord, but its exact nature is unknown.

Symptoms.

The dog, cat and wolf are the commonest subjects of rabies.

In man there is a history of a bite by an infected animal after which there is an incubation period of 7 days to 2 years.

There is then a period of depression with anxiousness, sleeplessness, dryness of the throat, and discomfort at the old healed scar.

A stage of excitement follows, with terror, hallucinations, hyperæsthesias, throat spasms and a hoarse cough.

Death from respiratory spasm and asphyxia occurs about the 3rd day after the onset of symptoms.

Transmission.

Only by an infected bite.

Prevention.

Destruction of suspicious animals. Muzzling of all animals in infected places. Destruction of pariahs. Quarantine against infected ports or countries.

XI. INFLUENZA.

Synonyms.

La Grippe ; epidemic catarrhal fever.

Geographical Distribution.

Ubiquitous.

Etiology.

B. influenza (Pfeiffer).

A minute, non-motile rod. It does not grow on plain gelatin, and is decolorised by Gram.

Symptoms.

There is an incubation period of 1 to 3 days.

There is a sudden onset, with chills, fever, and aches all over. A transient rash may occur, but is not constant. There is prostration and mental depression. The temperature falls on 3rd or 4th day and the symptoms abate.

There is no seasonal or age predilection. The mortality is only about 0·1 %.

Transmission.

Probably always aërial.

Prevention.

Isolation of sick, and disinfection of nasal and oral discharges.

XII. MALARIA.

Synonyms.

Ague, Intermittent fever.

Geographical Distribution.

Occurs in most parts of the world. The "malignant tertian" variety has more of a tropical distribution; the "quartan" a temperate one; while the "benign tertian" is found everywhere.

Etiology.

The disease is due to one of three species (*H. vivax* in benign tertian; *H. malariæ* in quartan fever; and *H. præcox* in malignant tertian) of the genus Hæmamœba; order Hæmosporidia; class Sporozoa; kingdom Protozoa.

These parasites were discovered by Laveran in 1880.

The theory of the intermediate agency of the mosquito in propagating the disease was proved by Ross in 1897, who traced the extra-corporeal phase of the parasite within the body of that insect.

The parasite is introduced by the mosquito, when biting, in the form of spores known as *sporozoites* or *zygotoblasts.* These enter red corpuscles and grow, and are called *trophozoites.* After varying times from 48 to 72 hours the parasites are full grown, occupying all the corpuscle. They then divide up into a number of spores called *merozoites*, which become free, and each of them attack a new red corpuscle to form fresh trophozoites. Thus there is an endless developmental cycle in the human body.

Certain of the trophozoites will always go on to sporulation (*schizonts*); but there are some which do not (*sporonts*), and these take on sexual characteristics and become male and female *crescents* or similar bodies.

A mosquito will feed on infected blood, and then the sexual sporonts will become differentiated, matured and fertilised in the mosquito's stomach, and are then known as *zygotes.* The zygote becomes elongated, pierces the stomach wall (*vermicule* or *oökinete*) and there matures. The protoplasm divides to form *sporoblasts.* The nuclei of the sporoblasts then develop within the cyst and form spindle-shaped spores known as *sporozoites.* These work through the mosquito's tissues and reach the salivary glands, whence they can infect a fresh human host when the mosquito next feeds.

This exogenous cycle in the mosquito lasts about 12 days.

Not all mosquitoes can thus act as efficient hosts. The following species are all that are at present known to be incriminated. They all belong to the sub-family *Anophelinæ* (Theobald).

Anopheles maculipennis.
Anopheles bifurcatus.
Anopheles jesoensis.
Anopheles algeriensis.
Cellia albipes.

Myzorhynchus pseudopictus.
Myzorhynchus paludis.
Myzomyia hispaniola.
Myzomyia funesta.
Myzomyia listoni.
Myzomyia culicifacies.
Nyssorhynchus lutzi.
Nyssorhynchus cubensis.
Nyssorhynchus maculatus.
Pyretophorus superpictus.
Pyretophorus costalis.

Most of the above mosquitoes can be distinguished from the *Culicinæ* by the fact that their wings are spotted, that their position at rest is rather vertical than horizontal to the surface of support, and that their larvæ breathe horizontally at the surface of water instead of depending head-downwards as in the case of other sub-families.

Symptoms.

The parasites, when they have multiplied sufficiently (12 to 21 days), cause a febrile reaction. There is a rigor followed by a hot stage, then a profuse diaphoresis, and then an abatement of symptoms.

If the parasite is *H. vivax*, such a paroxysm will be repeated every other day, with the temperature normal on the intervening day. If the parasite is *H. malariæ*, the paroxysms will occur every third day, leaving an interval of two clear days between each attack.

In malignant malaria (*H. præcox*) the temperature tends rather to be continued or remittent throughout the attack.

The spleen is markedly enlarged in malaria, and a malarial cachexia is not infrequently established.

Prevention.

Cases should be isolated by mosquito-curtains.

Anti-mosquito campaigns should be carried out.

Native houses should not be allowed near European quarters.

Prophylaxis can be secured by the use of quinine.

XIII. MEASLES.

Synonym.

Morbilli.

Geographical Distribution.

Ubiquitous.

Etiology.

The specific organism has not yet been identified.

Symptoms.

After an incubation period of 14 days, the primary fever sets in, accompanied by pronounced coryzal symptoms. A slightly-raised patchy rash occurs on the fourth day of the fever, but the disease is highly infectious for two days before the rash appears. The rash first appears on face and neck, and later spreads to the body.

The period of eruption marks a secondary rise of the fever, which had begun to decline on the second or third day.

On the seventh or eighth day of the disease a crisis occurs ; the temperature falls and the rash fades, until by the tenth day there is only a branny desquamation.

Bronchitis, broncho-pneumonia and pleurisy are frequent complications or sequelæ.

The disease is most common in June and December, and amongst children of three to five.

Transmission.

Probably always aërial.

Prevention.

Isolation of the sick and suitable disinfection of nasal discharges and of the sick-room.

The infection ceases not less than 2 weeks from the appearance of the rash. The quarantine against contacts should be 16 days.

XIV. MUMPS.

Synonym.

Epidemic parotitis.

Geographical Distribution.

Common in temperate climates.

Etiology.

The specific organism has not yet been identified.

Symptoms.

There is an incubation period of 8 to 21 days.

There is a sudden onset of fever, followed (in 1 to 3 days) by enlargement of parotid and submaxillary glands. It is at first unilateral and then generally bilateral.

Orchitis is common about the eighth day. It chiefly occurs in the spring and autumn, and in children of five to fifteen.

Transmission.

Aërial.

Prevention.

Isolation. Disinfection and quarantine of 3½ weeks against contacts.

XV. PLAGUE.

Synonyms.

Pestis bubonica; Black death.

Geographical Distribution.

At one time or another the disease has spread almost over the whole globe.

At the present time it appears to be endemic in India and China.

Etiology.

B. pestis, discovered in Hong Kong by Kitasato.

A short round-ended rod, with a faculty for bi-polar staining.

It is non-mobile, does not liquefy gelatin, and is decolorised by Gram.

The disease is very common amongst nearly all rats. From them it spreads to man (or from man to man) by means of fleas.

If the plague is amongst the "large brown" rats (*Mus decumanus*), there is less chance of human infection, since these rats are cellar and drain rats, who do

not live in very close proximity to man. Consequently, when they migrate and leave their dead and dying, their fleas (*Ceratophyllus fasciatus*), who leave them for another host, do not find a human host within reach.

If the plague is amongst black rats (*Mus rattus*), which used to be common in Europe at the time of the Great Plague, then human infection is very likely, for these rats are house rats, living with or near man, and their fleas (*Læmopsylla cheopis*) can easily find a human host to bite.

Symptoms.

There is an incubation period of 1 to 3 days.

There is usually a sudden onset with headache, giddiness, and high fever. The face is flushed with injected conjunctivæ, and the expression anxious.

There is a reeling, drunken gait; the tongue is furred, with red tip and edges.

The pulse is full and fast, but of low tension.

Very soon one of the lymphatic glands becomes swollen and indurated—usually the inguinal.

The maximum temperature is reached on the second or third day.

Another type less common and more fatal is the *pneumonic*, with a primary plague, confluent lobular pneumonia.

Or, a *septicæmic* type, probably induced by the ingestion of the organism. This is also rarer, and is rapidly fatal.

There is also a mild type of the disease known as *Pestis minor*, with a very slight glandular enlargement, one or two days' mild fever, and no constitutional disturbance.

The mortality in *Pestis major* is from 30 to 70 % or more.

Transmission.

The bubonic variety is probably nearly always carried by fleas.

The pneumonic, by infected expectoration of a pneumonic patient.

The septicæmic, by ingestion of infected food-stuff.

Prevention.

Infection does not cease for about 8 weeks from the onset of the disease.

Quarantine against contacts should be 12 days.

Prophylaxis is secured by inoculations with Haffkine's serum.

XVI. RELAPSING FEVER.

Synonyms.

Spirillar fever, Tick fever, Famine fever.

Geographical Distribution.

It is found in Europe, India, China, Palestine and West Africa.

Etiology.

Due to two species of blood spirilla.

(1) *S. obermeieri*, found by Obermeier in 1873, and is the cause of the relapsing fever of Europe and India.

The intermediate host may be a bug, flea, or some gnat.

(2) *S. duttoni*, found by Dutton and Todd in 1904, and is the cause of the tick fever on the Congo.

It is carried by a tick—the *Ornithodorus moubata.*

Symptoms.

There is an incubation period of 3 to 7 days.

There is a sudden onset, with quick rise of temperature, headache, backache and prostration.

After continuing for 3, 5 or 7 days, there is a sudden crisis with diaphoresis. The symptoms rapidly disappear, and the patient feels almost well.

After an afebrile interval of about 7 to 9 or more days, a relapse occurs, and the symptoms are repeated.

On rare occasions a second or third relapse may take place.

Transmission.

By some intermediate zoological host as stated under "Etiology."

Prevention.

Isolation of sick. Cleanliness of dwelling and person.

XVII. SCARLET FEVER.

Synonym.

Scarletina.

Geographical Distribution.

Confined to most temperate climates except Asia Minor and Japan.

Etiology.

Several streptococci have been described, but sufficient proof has not been forthcoming.

Symptoms.

There is an incubation period of 1 to 5 days.

There is a quick onset of fever, and on the second day a rash appears, being a general scarlet blush, occurring first on the stomach and flexor surfaces of the limbs, and then spreads to the rest of the body.

The throat and fauces are also attacked with injection and swelling of tonsils and pharynx.

The rash usually lasts about 4 days, and is gone by the seventh or eighth day, being followed by a flaky desquamation lasting for several weeks.

The temperature suddenly falls on about the sixth day.

Complications may comprise: Acute tubular nephritis at about the end of the fever; sloughing of tonsils; rheumatic morbus cordis; otitis media and perforation of the tympanum.

The disease is most prevalent in October, and between the ages of one and ten.

The mortality is about 5 %, but is greater in children under the age of five.

Transmission.

Aërial.

Prevention.

Isolation, notification, disinfection. Infection lasts till desquamation has ceased (*circa* 7 weeks).

Quarantine against contacts 7 days.

XVIII. SMALL-POX.

Synonym.

Variola.

Geographical Distribution.

Ubiquitous. The main endemic and epidemic centres are, however, tropical.

Etiology.

B. albus variolæ (Klein).

A small rod-shaped non-mobile bacillus, which does not liquefy gelatin, and is stained by Gram.

Symptoms.

The incubation period is 12 to 14 days.

There are prodromal symptoms of headache and pain in the lumbar region.

The temperature rises and attains a maximum on the second day. On the third day the eruption appears, consisting of hard, shotty papules, first seen on the forehead and face, then on hands, wrists, ankles and feet, and later over the whole body. They also occur on the buccal mucous membrane.

By the fifth day of the eruption the papules have all become vesicular, accompanied by some subcutaneous œdema. None of the vesicles are oval, and they do not collapse when pricked.

By the eighth or ninth day of the eruption the vesicles have become pustular, and there is now a secondary rise of temperature due to pyogenic infection.

Other types occur, such as the "discrete," the "confluent" and the "hæmorrhagic."

Keratitis and corneal ulceration are frequent complications. The mortality is about 35 % in the unvaccinated, and 5 % in the vaccinated.

The disease is most prevalent in the spring and winter, and all ages are liable, though it is rare after fifty.

Transmission.

This is aërial, and can act over considerable distances. Thus an infected centre such as a small-pox hospital may infect the neighbourhood.

Prevention.

Isolation, notification, disinfection, vaccination.

Infection lasts till the scabs are all gone (*circa* 6 weeks).

Quarantine against contacts should be 16 days.

XIX. TRADE TOXICOLOGY.

(1) **Lead.**

Poisoning occurs amongst ore-smelters, red and white lead-workers, type-founders, wall-paper makers, house-painters, lead-workers and linoleum makers.

Women are especially liable.

The lead may be ingested or inspired.

The *symptoms* are : Headache, colic, constipation and blue line on the gums.

(2) **Phosphorus.**

Occurs amongst match- and phosphorus-workers.

The phosphorus enters by respiratory tract.

The *symptoms* are : Yellow skin, garlicky breath, anæmia, albuminuria and necrosis.

It takes 3 or 4 years to act.

(3) **Mercury.**

Occurs amongst mercury miners, smelters, battery makers, water-gilders, bronzers, etc.

It enters per lungs, alimentary canal or skin.

The *symptoms* are : Salivation, fœtor of breath, brittle teeth, red line on gums, diarrhœa and tenesmus, tremors of muscles, amnesia and delirium.

(4) **Copper.**

Occurs amongst ore-smelters, copper-smiths, etc.

Entrance by respiratory and intestinal tracts.

Symptoms.

Colic, bronchitis, asthma, green line on gums, green coloration of hair or teeth.

(5) **Zinc.**

Occurs amongst zinc-smelters, colour-mixers, calico-printers, galvanisers, makers of artificial meershaums, wirers of champagne bottles.

Symptoms.

Headache, giddiness, sweating, cramps, dyspnœa, cough, nausea, vomiting, hyperæsthesia, paresis.

(6) **Arsenic.**

Occurs amongst ore-smelters, dye-workers, cosmetic makers, artificial-flower makers, toy makers, wall-paper makers, fly-paper makers, chromo-lithographers, taxidermists and shot makers.

Symptoms.

Nausea, vomiting, thirst, diarrhœa, dysphagia, pigmentation of skin, peripheral neuritis.

(7) **Antimony.**

Occurs amongst ore-smelters and type-founders.

Symptoms.

Colic, diarrhœa and urethral pains.

XX. TYPHUS FEVER.

Synonym.

Jail fever.

Geographical Distribution.

It is now mildly endemic in Britain and Russia, and can become epidemic in most temperate regions, but is rare in the tropics.

Etiology.

No specific organism has been identified.

Symptoms.

There is an incubation period of 12 days.

There is a sudden onset with frontal headache, rigors, and pyrexia. The rash, of a mulberry appearance, occurs on the fifth day, usually first on the arms or hands.

The fever is continued, and is accompanied by pronounced nervous symptoms.

It terminates (in favourable cases) by crisis on the fourteenth day.

It is largely predisposed to by insanitary surroundings and overcrowding.

Most cases occur in the winter, and amongst young adults.

Transmission is aërial.

Prevention.

Notification, isolation, disinfection.
Infection persists for about 5 weeks.
Quarantine against contacts should be put at 14 days.

XXI. VACCINIA.

Synonym.

Cow-pox.

Geographical Distribution.

Nearly everywhere.

Etiology.

It is a disease of the cow—called cow-pox, and is probably identical with the "grease" of horses and small-pox of man. If so it is due to the *B. albus variolæ* which causes the latter disease. Jenner, in 1798, found that cow-pox could be transferred to man (through abrasions), and would then give rise to a local eruption with fever, malaise, etc.; also, that such people were immune from human small-pox.

Thus vaccination was established, since when the deaths in England from small-pox have fallen to about 70 deaths per million per annum, as compared with over 5000 in Jenner's time.

XXII. WHOOPING COUGH.

Synonym.

Pertussis.

Geographical Distribution.

Widespread in most parts of the world.

Etiology.

So far unknown.

Symptoms.

There is an incubation period of 10 to 12 days. There is a catarrhal stage with a cough (often ending in retching) which lasts for 10 to 12 days.

There is then a convulsive stage with frequent severe bouts of coughing accompanied by the well-known inspiratory whoop due to spasm of the glottis. This stage, which lasts about 4 weeks, is followed by a stage of decline lasting 2 or 3 weeks. The

disease is most prevalent in the spring and autumn, and amongst children of 1 to 8.

The mortality is 2 to 5 %.

Transmission.

Aërial.

Prevention.

Isolation, notification, disinfection.
The infection lasts about 8 or 9 weeks.
Quarantine against contacts should be put at 14 days.

XXIII. YELLOW FEVER.

Synonym.

Black vomit.

Geographical Distribution.

Endemic centres are—

West Indies.
Mexico.
West Africa.
Brazil.

Sporadic cases have been imported into Europe, but the disease has never spread. It is unknown in Australia and Asia.

Etiology.

The germ is unknown. It must be ultra-microscopical, for it will pass through the Chamberland F bougie, but not through the B bougie.

Sanarelli's *B. icteroides* is now only of historical interest.

The disease is carried from man to man by a mosquito—the *Stegomyia fasciata*, and no other mosquitoes have yet been incriminated.

The serum of a patient is virulent only during the first 3 days of the disease.

If a stegomyia bites during these 3 days, a further

period of 12 days must elapse before it is capable of infecting someone else.

The serum of a convalescent has both prophylactic and curative properties.

The disease is in no sense contagious.

FIG. 61.—TYPES OF BACTERIA (*Drawn to scale*).

a Red corpuscle.
b Anthrax.
c Tubercle.
d Diphtheria.
e Plague.
f Tetanus.
g Cholera.

(NOTE.—Stained specimens of the above characteristic bacteria are frequently given to D.P.H. Students for identification.)

Symptoms.

There is an incubation period of 3 to 5 days. The onset is sudden, with severe frontal headache and fever. The face is red and swollen. There is intense thirst and epigastric oppression, vomiting is frequent. The urine is scanty and contains albumin from the second day.

About the third day the symptoms abate. In favourable cases gradual convalescence is established. In bad cases the fever mounts again, black vomit sets in, and intense jaundice appears, death occurring between the fourth and tenth day.

The mortality will vary from 7 to 30 or more per cent.

Prevention.

Isolation of sick by mosquito nets for first 3 days. Anti-mosquito campaigns. Inoculations with protective serum.

CHAPTER XVIII

VITAL STATISTICS

By this we signify the science of figures as applied to the health-history of towns and countries.

They deal with the influences affecting vitality, such as birth-rates, death-rates, marriage-rates, increase or decrease of population, incidence of disease, and other such facts, the analysis of which forms the foundation of all sound inquiry as to sanitary progress.

In making calculations the various processes will be often much simplified by making use of **logarithms**, a brief *résumé* of which will therefore not be out of place here.

Every one knows that $1000 = 10^3$. The number 3, which represents the power to which 10 must be raised to be equal to 1000, is called the logarithm of 1000, and written "log. 1000."

In the same way 2 is the logarithm of 100, since $10^2 = 100$.

It follows that log. $10 = 1$, and log. $0{\cdot}1 = -1$.

We can therefore define it as follows—

The logarithm of a number N is the value of x, which satisfies the equation $a^x = \mathrm{N}$, where a is a given number.

Logarithms were first invented by John Napier of Merchiston, in Scotland, in 1614. These are called Naperian or *hyperbolic logarithms*, and are used in higher mathematical investigations, the value of the base "a" being denoted by the letter e of value 2·71828. . . .

For ordinary arithmetical calculations it was proposed by Henry Briggs, of London and Oxford, in 1617, to use the number 10 as a base for logarithms, and Briggs' tables are known as *common logarithms*, and tables are published containing the logs. of numbers 1 to 100000 to as much as 14 places of decimals.

The Characteristic.

It will be recognised that $10^{2 \cdot 5}$ must be a number larger than 10^2 (*i.e.* 100), but smaller than 10^3 (*i. e.* 1000). The logs. of the numbers between 100 and 1000 will therefore be decimals which are larger than 2 but smaller than 3.

Thus it can be shown that log. 500 = 2·6990.

In this, as in all other logarithms, *the whole number* (i. e. here = 2) *is called the "characteristic," and the decimal* (i. e. here = 0·6990) *is called the "mantissa."*

This characteristic may be either positive or negative.

If negative, a minus sign is written over the integer (*e. g.* $\bar{2}$). It is not written *before* it, since the mantissa itself is always positive.

The characteristics can always be found by the following simple rules—

(*a*) For numbers greater than unity the characteristic is *positive*, and is smaller by 1 than the number of digits which precede the decimal point (*e. g.* log. 3678 = 3·5657. Here the characteristic must be 3, because there are four figures in the number 3678).

(*b*) The characteristic of the logarithm of a number less than 1 is *negative*, and is a number which is greater by 1 than the number of noughts which follow the decimal point (*e. g.* log. 0·43758 = $\bar{1}$·6410575. Here the characteristic is negative, and is 1 because no noughts follow the decimal in the number 0·43758. Or, again, log. 0·006004 = $\bar{3}$·7785. Here the characteristic is negative because 0·006004 is less than unity, and it is 3 because that number is one greater than the number of noughts which follow the decimal point).

The Mantissa.

We have seen that it is quite easy to calculate the characteristic of any number; but to calculate the mantissa is very difficult, unless the numbers (of which the logarithms are required) are integral powers of 10, in which case the mantissa is 0 (*e. g.* log. 100 = 2·0. Log. 10 = 1·0).

The mantissæ have been worked out, and can be found in a *table of logarithms.*

The mantissæ of the logs. of all numbers which contain the same significant figures are identical, no matter whether the numbers are greater or less than unity. The same table of logs. can therefore be used to find the mantissæ of all numbers whatever their magnitude.

The mantissæ are *always positive.*

The table of logarithms does not contain characteristics, which must be supplied by yourself.

The following is the sample of the top of a page in a table of logs., to show method of procedure—

	0	1	2	3	4	5	6	7	8	9	1 2 3 4	5	6 7 8 9	
55 56 etc.	7404 7412	7412 etc.	7419	7427	7435	7443	7451	7459	7466	7474	1 2 2 3	4	5 5 6 7	

The first *column* and the first *row* (printed in heavy type) contain the numbers whose mantissæ are given.

The first *column* contains the first two figures of the number whose mantissa is required ; the first *series of nine figures in the first row* contains the third figure of the number whose mantissa is required ; while the second series of nine figures contains the fourth figure (*e.g.* using the sample line given—

$$
\begin{aligned}
\text{Log.}\quad 55 &= 1{\cdot}7404 \\
550 &= 2{\cdot}7404 \\
555 &= 2{\cdot}7443 \\
5{\cdot}59 &= 0{\cdot}7474 \\
0{\cdot}5543 &= \bar{1}{\cdot}7435 + 0{\cdot}0002 = 1{\cdot}7437 \\
5529 &= 3{\cdot}7419 + 0{\cdot}0007 = 3{\cdot}7426).
\end{aligned}
$$

Having got a logarithm, and wishing to find the number to which it corresponds, we make use of *tables of antilogarithms*, which are used in exactly the same way.

By means of the above tables we can easily find the log. of any number of five figures or less. If we wish to find the log. of a number with more than five figures, some calculation is required which is facilitated by the use of a *table of proportional parts.*

It will be noticed that the differences between the logs. of numbers differing by 1 in the fifth figure remain remarkably constant for many successive numbers. Thus from 66500 to 67500 the difference between any two consecutive logs. is 65 (*e. g.*—

$$
\begin{aligned}
\text{Log. } 66511 &= 4{\cdot}8228935 \\
66512 &= 4{\cdot}8228935 + 0{\cdot}0000065 = 4{\cdot}8229).
\end{aligned}
$$

Say, now, we want to find log. 6651137. We first find it in five figures, log. 66511 = 4·8228935.

Now since a difference of 1 in the fifth figure = 65, $\therefore$ a difference of 0·37 will make a difference of $65 \times 0{\cdot}37 = 24$.

$$
\begin{aligned}
\therefore \text{log. } 66511{\cdot}37 &= 4{\cdot}8228935 + 24 = 4{\cdot}8228959 \\
\therefore \text{log. } 6651137 &= 6{\cdot}8228959
\end{aligned}
$$

Application of Logarithms.

We can use them for the **multiplication** of unwieldy numbers, *e.g.* find the product of—

$$123{\cdot}4 \times 45{\cdot}56 \times 6{\cdot}789$$

Let $x = 123{\cdot}4 \times 45{\cdot}56 \times 6{\cdot}789$
Then $\log. x = \log. 123{\cdot}4 + \log. 45{\cdot}56 + \log. 6{\cdot}789$

because logs. are indices of the same number, and the multiplication of the powers of the same number merely involves the addition of their indices.

Now by reference to table of logs. we find—

$$\begin{aligned}\text{Log } x &= 2{\cdot}0913 + 1{\cdot}6586 + 0{\cdot}8318\\ &= 4{\cdot}5817\end{aligned}$$

This mantissa 0·5817 is found by the table of antilogarithms to be the log. of 3817

Therefore $x = 38170$, since the characteristic was 4. Therefore we have—

To multiply numbers, add their logs. and find the number corresponding to the log. thus obtained.

In the same way **we can divide numbers by subtracting their logs.**

In case of subtraction of logs., we change the sign of the characteristic in the lower line and then add the characteristics after subtracting the mantissæ. (*E. g.*—

$$\begin{array}{rl} \text{From} & \bar{2}{\cdot}3468537 \\ \text{Subtract} & \bar{5}{\cdot}7654626 \\ \hline & 2{\cdot}5813911 \end{array}$$

Here 1 is carried over from the mantissa and has to be subtracted from $\bar{2}$, giving $\bar{3}$.

Then changing the $\bar{5}$ into 5 and adding to this the $\bar{3}$, we have the 2).

Involution (or raising of powers) **is performed by multiplication of the log. by the index of the power.**

E. g. raise 749 to the third power (*i. e.* cubed).

Now $\log. 749 = 2{\cdot}8745$
and $2{\cdot}8745 \times 3 = 8{\cdot}6235$

The number corresponding to this is 420300000 which $= 749^3$.

Evolution (or the extraction of roots) **is performed by division of the log. of the number by the index of the root.**

E.g. find the cube root of 79.

Now $\log. 79 = 1{\cdot}8976$

$1{\cdot}8976 \div 3 = 0{\cdot}6325$

By reference the number corresponding to mantissa 0·6325 is 4290.

$$\sqrt[3]{79} = 4{\cdot}29 \text{ (approx.)}.$$

POPULATION.

In order to calculate rates we must know the populations on which they are to be estimated.

This is ascertained in two ways—

1. Census enumeration.
2. Intercensal estimation.

The **census** in Great Britain was first made on **10 March, 1801**, and has been made every ten years since. It should—

(*a*) Be taken simultaneously all over the country on a definite night.
(*b*) Enumerate the number in a house.
(*c*) „ „ sexes.
(*d*) „ „ ages.
(*e*) „ „ professions.
(*f*) „ „ relationships.
(*g*) „ „ birthplaces.
(*h*) „ „ infirmities.

The **natural increment** is represented by the excess of births over deaths.

The **actual increment** is the increment found by enumeration, and will be influenced by emigration and immigration.

At the actual census the "actual increment" is found.

In intercensal estimations we have to calculate the increase or decrease between the two previous census enumerations and assume that this will be maintained. The increase, of course, will not be in arithmetical

progression, since not only are births taking place, but the number of people capable of reproducing the species are continually increasing.

The increment will therefore be in *geometrical progression* and this geometrical progression will be regular when the ratio of the births to the deaths remains constant.

The assumption as to the rate of increase will not always hold good for any definite locality, since the population may be increased by new industries, exploitation of health-resorts, etc.

Greater reliability of estimated populations would be obtained if the census were quinquennial; and a midsummer census would be better than a spring census, as the death-rate is calculated on the estimated population at the middle of the year, and the increment of an additional quarter would not have to come into the calculations.

A useful method for checking the estimation of population in any given locality is that suggested by Newsholme. It is based on the assumption that the birth-rate remains the same for a series of years.

Thus if the birth-rate is x per 1000 for one decennium, and the number of births in a given year is y,

$$\text{Then } \frac{y \times 1000}{x} = \text{population in that year.}$$

The *official method* of the Registrar-General *for estimating the population* is as follows—

First.—To get ratio of annual increase—

$$\left.\begin{array}{c}\text{Log. of ratio}\\\text{of annual}\\\text{increase}\\= \text{log. } x\end{array}\right\} = \frac{\text{Log. of recent census} - \text{log. of previous census}}{10}$$

$$\left.\begin{array}{c}\text{Log. of pop.}\\\text{at middle of}\\\text{census year}\end{array}\right\} = \text{Log. of last census} + \tfrac{1}{4}\text{ log. } x.$$

$$\left.\begin{array}{c}\text{Log. of pop.}\\ \text{at middle}\\ \text{of year } y\end{array}\right\} = \left\{\begin{array}{c}\text{Log. of last}\\ \text{census}\end{array}\right\} + \frac{\log. x}{4} + \left(\log. x \times \begin{array}{c}\text{No. of years}\\ \text{since last}\\ \text{census}\end{array}\right)$$

Or, expressed in words—

"From the log. of the most recent census subtract the log. of the previous census, and then divide the log. so obtained by 10, and the quotient will be the log. of the ratio of annual increase.

"Add quarter of this to the log. of the last census and the sum will be the log. of the population at the middle of the census year.

"To this sum add the log. obtained by multiplying the log. of the rate of annual increase by the number of years intervening since the last census, and the sum will represent the log. of the estimated population at the beginning of the required year."

REGISTRATION OF BIRTHS.

Births, deaths and marriages have been registered since the days of Elizabeth, but it was not until 1837 that an Act (6 and 7 Will. IV. c. 86) was passed nationalising the registration and establishing the office of Registrar-General.

Dr. Farr was the first holder of that office, and the first report was issued in 1839.

A further Act on the subject was passed in 1874—the "Births and Deaths Registration Act."

By this Act all births must be registered within 42 days.

The **Crude Birth-rate**, which is recorded in the Official Returns, is the number of births occurring annually per 1000 of the mean population living at all ages.

$$\text{C.B.R.} = \frac{\text{Births in year} \times 1000}{\text{Estimated pop. in middle of year}}$$

(In 1874 the C. B. R. for England and Wales was 36·3 per 1000, but has since steadily declined.)

The **Rational Birth-rate** is the number of annual births per 1000 of women, aged 15 to 45, and living in the conjugal state.

In this country male births are to female as 104 is to 100.

In this country the *illegitimate birth-rate* is declining, having sunk in 1903 from a former 5 per 1000 persons living to 1·2 per 1000 (or 39 per 1000 births).

The custom of stating the illegitimate births as a percentage of total births is not sound, for the same number of illegitimate births might appear as a higher or lower proportion according to the rise or fall of the total births. They ought therefore to be expressed as a rate per 1000 possible mothers (*i. e.* unmarried women and widows between 15 and 45).

The crude birth-rate has been declining throughout Europe for some years, the reasons being—

(*a*) Later marriages.
(*b*) Increase of celibacy.
(*c*) Malthusian psychoses.

The Birth-rate is highest—

(*a*) In towns.
(*b*) In industrial districts.
(*c*) In national prosperity.
(*d*) In the first half of the year.
(*e*) Amongst the poorer classes.
(*f*) Amongst certain nationalities (*e. g.* Jews and Hungarians).

The Birth-rate is lowest—

(*a*) In agricultural districts.
(*b*) In time of war.
(*c*) In the second half of the year.
(*d*) Amongst the upper classes.
(*e*) Amongst certain nationalities (*e. g.* French).

THE MARRIAGE-RATE.

The marriage-rate means the number of marriages per annum per 1000 of the mean population at all ages.

Of course the rational rate would be the proportion per 1000 of unmarried marriageable adults.

The *mean age at marriage* is, unfortunately, rising, which tends to diminish the birth-rate.

The *fecundity of marriage* depends on—

(*a*) Age at marriage.
(*b*) Duration of married life.
(*c*) Venereal history.
(*d*) Personal idiosyncrasy.

The *natality* or probability of birth can be calculated for the age of the individual parents, and also for the combinations of the parents' ages.

Remarriages.

These have of late been diminishing.

10 % of the males who marry are widowers, and 7 % of the women who marry are widows.

DEATH-RATES.

Every death must be registered within 5 days.

The **Crude Death-rate** (or Recorded Annual Death-rate) is *the ratio of the number of deaths in a year to the estimated population in the middle of the year*, and is recorded (like a birth-rate) in deaths per 100,000 of the estimated population.

$$\text{D.R.} = \frac{\text{Deaths in year} \times 1000}{\text{Estimated pop. in middle of year}}$$

The **Actual Death-rate** is a rate with corrections for deaths of strangers, hospitals and workhouses, etc., who do not belong to the district.

The **Weekly Death-rate** is frequently recorded by

H.O.s of large towns. In order to get an estimated population as a basis to work on the R.-G. divides the estimated population for the middle of the year by 52·17747 to obtain, as it were, a weekly population of the town which can be assumed as remaining constant.

$$\text{W.D.R.} = \frac{\text{Weekly deaths} \times 52{\cdot}17747 \times 1000}{\text{Estimated pop. in middle of year}}$$

The **Standard Death-rate** is the average death-rate at all ages during the previous intercensal decade. It is based on decennial and not on annual or weekly data.

It serves to show how age and sex distribution is or is not favourable to a low death-rate, but is no guide to comparative healthiness.

It is computed as follows :—

First Process :—

$$\left\{\begin{array}{c}\text{Calculated}\\ \text{deaths amongst}\\ \text{males in age}\\ \text{group 0–5}\end{array}\right\} = \frac{\left\{\begin{array}{c}\text{Mean ann. death-rate}\\ \text{for whole decade}\\ \text{for this period}\end{array}\right\} \times \left\{\begin{array}{c}\text{No. of living}\\ \text{males per last}\\ \text{census, of this}\\ \text{age period}\end{array}\right\}}{1000}$$

Similar calculations are then made for each age group of each sex, and then these calculated deaths are all added together.

Second Process :—

$$\text{S.D.R.} = \frac{\text{Sum of calculated deaths} \times 1000}{\text{Population}}$$

This standard death-rate holds good for the decennium, and is a means of correcting the annual rates.

The **Corrected Death-rate** of a place is the death-rate which would have been recorded in a place if the

age and sex distribution had been the same as that of the country as a whole.

$$\text{C.D.R.} = \text{A.D.R.} \times \text{factor}$$

(NOTE.—This factor is—

$$\left(\frac{\text{Av. ann. death-rate of country}}{\text{Standard death-rate of district}}\right)$$

Comparative Mortality Figure.

This is a figure obtained by reducing the Annual Death-rate of the country to 1000, and comparing the corrected death-rate of a district with it.

It is found by a proportion sum :—

$$\left\{\begin{matrix}\text{A.D.R. for}\\ \text{country}\end{matrix}\right\} : \left\{\begin{matrix}\text{C.D.R.}\\ \text{of town}\end{matrix}\right\} :: 1000 : \left\{\begin{matrix}\text{Compar. Mortal.}\\ \text{Fig. of the town}\\ \text{for the year}\end{matrix}\right\}$$

It is useful in comparing the corrected death-rates of different places, both with each other and with the mortality of the whole country.

$$\text{C.M.F.} = \frac{\left\{\begin{matrix}\text{C.D.R.}\\ \text{of town}\end{matrix}\right\} \times 1000}{\text{A.D.R. for country}}$$

The following table (quoted by Lewis and Balfour) will show the figures of a few towns :—

	Standard Death-rate.	Factor for Sex and Age Distribution Correction.	Recorded Death-rate, 1899.	Corrected Death-rate.	Comparative Mortality Figure.
England and Wales . .	19·15	1·0000	18·33	18·33	1000
London . .	17·97	1·0656	19·78	21·08	1150
Birmingham	17·33	1·1050	20·84	23·03	1256
Manchester .	16·90	1·1331	24·61	27·89	1522
Liverpool .	17·44	1·0980	26·38	28·97	1580

INFANTILE MORTALITY.

As many very small infants are returned in the census as "1 year old," the infantile population cannot be accurately estimated for purposes of calculation.

It is therefore expressed as *deaths of children under* 1 *year per* 1000 *births in the same year.*

(NOTE.—The average varies from 140 to 150.)

The mortality is greatest on the first day of life, and about 50 % occurs during the first 3 months.

It is so much higher amongst males than females as almost to neutralise the preponderance of male births.

It is much higher in large towns.

The *causes* may be summed up—

(*a*) Early marriages.
(*b*) Weakly parents.
(*c*) Hereditary tendencies.
(*d*) Insanitary surroundings.
(*e*) Improper feeding.
(*f*) Exposure and insufficient clothing.
(*g*) Infant life assurance.

AGE GROUP DEATH-RATES.

These should always be expressed as a number per 1000 of those living *at that age.*

Age distribution is the only real basis on which the relative value of death-rates can be determined.

The birth-rate will only affect the death-rate in so far as it affects the age-constitution of the population of any place.

There is no constant relation between the death- and birth-rates.

A continued high birth-rate bespeaks a large reproductive population, whose low mortality more than counterbalances the high infantile mortality.

A high birth-rate in conjunction with a high death-rate points to excessive infantile mortality.

Sex distribution.

At almost all ages the death-rate amongst females is less than the death-rate amongst males. Hence the death-rate tends to be lowered where females are in excess.

Causes of death.

To avoid errors we need—

(*a*) Uniformity of nomenclature.
(*b*) Sound diagnosis.
(*c*) Accuracy of returns.

Classification.—The Registrar-General classifies the causes of death in 8 groups—

(*a*) Zymotic (including febrile, specific, epizootic and septic diseases).
(*b*) Parasitic.
(*c*) Dietetic (*e. g.* scurvy and alcoholism).
(*d*) Constitutional (*e. g.* tubercle).
(*e*) Developmental (*e. g.* congenital diseases and senility).
(*f*) Local (*e. g.* of the various body systems).
(*g*) Violence (*e. g.* suicide, accident, execution).
(*h*) Non-specified causes.

This classification is out of date and much needs revision.

Seasonal mortality.

Death-rates vary very much with the season of the year.

A mild winter lowers the mortality amongst the old and feeble. A cool summer lowers the infantile mortality by checking diarrhœa.

The various specific fevers have a fairly regular

mortality curve of their own, as the following table will show—

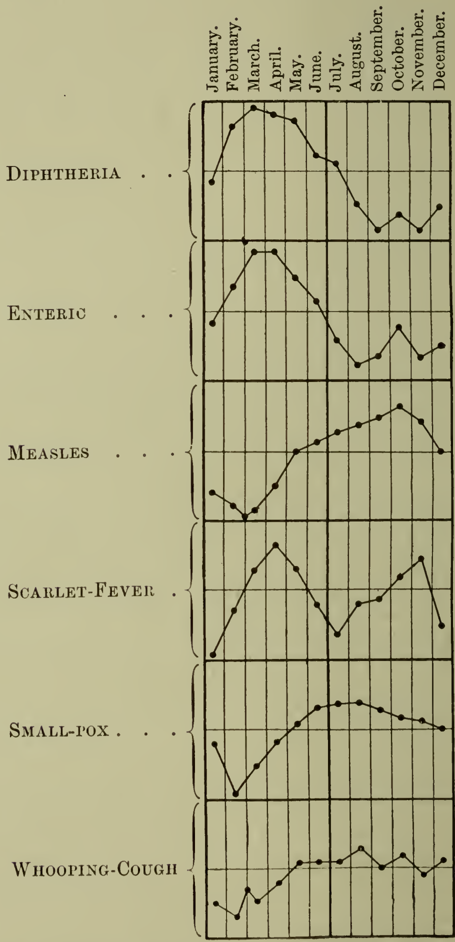

Fig. 62.—Zymotic Mortality (*after Lewis and Balfour*).

LONGEVITY AND LIFE TABLES.

The **mean age at death.**

$$\text{M.A.D.} = \frac{\text{Sum of ages at death}}{\text{Number of deaths}}$$

This is a fallacious indication of longevity unless an entire generation is under consideration, and is, moreover, no test of the sanitary condition.

The **probable duration of life** (" vie probable ") is *the age at which any number of children born into the world will be reduced to one half.*

This is not of much use as a longevity test.

In England and Wales 1,000,000 males are reduced to half before they reach their forty-seventh year. The same number of females are reduced to half by their fifty-second year.

The **mean duration of life.**

(" Vie moyenne "), or **expectation of life** at any age, is the average number of years which a person of that age has got to live, as shown by a life table.

Life capital.

The life capital of a community is the sum of the products obtained by multiplying the population at each age group by the mean expectation of life for that age group.

STATISTICAL FALLACIES.

Facts represented by numerical values are averaged by dividing the sum of the values by the number of facts (arithmetic mean).

In order that this average may be trustworthy—

(*a*) The facts must be accurate.
(*b*) „ „ numerous.

One of the statistical axioms is—"*the less the difference between the average and the figures of a series, the greater is its value.*"

Mean error.

Let the mean of certain observations = x.
Let the mean of observations above $x = y$.
" " " below $x = z$.
Then—

$$\textit{Mean error} = \frac{(y - x) + (x - z)}{2}$$

The greater the mean error the greater the need for more extended observations.

The **probable error** = mean error × 0·6745.

CHAPTER XIX

SANITARY LAW

THE law which deals with the sanitary condition of the kingdom is, in the main, based on four Acts—

(*a*) Public Health Act, 1875 (England and Wales).
(*b*) Public Health (London) Act, 1891 (Metropolis).
(*c*) Public Health (Scotland) Act, 1897 (Scotland).
(*d*) Public Health (Ireland) Act, 1878.

The Public Health Act of 1875 has been amended or supplemented by over a dozen different Acts, in order that sanitary legislation may be more or less brought up to date as are the London and Scotch Acts.

The following are some of the chief subsidiary Acts which concern the sanitarian.

(*a*) Public Health (Water) Act, 1878.
(*b*) Infant Life Protection Act, 1872.
(*c*) Canal Boats Acts, 1877 and 1884.
(*d*) Housing of the Working Classes Act, 1890.
(*e*) Factory and Workshops Acts, 1878, 1883, 1891 and 1895.
(*f*) Alkali Acts, 1881 and 1892.
(*g*) Food and Drugs Acts, 1875 and 1899.
(*h*) Rivers Pollution Prevention Act, 1876.
(*i*) Epidemic and other Diseases Prevention Act, 1883.
(*j*) Contagious Diseases (Animals) Act.
(*k*) Local Government Act, 1894.

(*l*) Isolation Hospitals Act, 1893.
(*m*) Burial Act, 1853.
(*n*) Public Health (Interment) Act, 1879.
(*o*) Disused Burial Grounds Act, 1884.

And also the following, which are *adoptive* in certain parts of the kingdom—

(*p*) Infectious Diseases (Notification) Act, 1889.
(*q*) Public Health (Amendment) Act, 1890.
(*r*) Infectious Diseases (Prevention) Act, 1890.

In addition to enactments, sanitation is also provided for by Bye-laws and Regulations.

Bye-laws.

Bye-laws are local rules made under statutory powers—

(1) To carry out details of a law.
(2) To facilitate the application of legal powers.

There are certain "Model Bye-laws" issued by the Local Government Board to serve as guides.

Bye-laws must be—

(*a*) Under S.A.'s common seal.
(*b*) Not repugnant to laws or act.
(*c*) Confirmed by L.G.B.
  1. Notice in newspaper one month.
  2. Ratepayers to have copy.
(*d*) Printed and hung up in S.A.'s office.
(*e*) Unable to inflict penalties of over £5 for each offence, or 40*s*. per diem for continued offence.

(Note.—All urban and rural S.A.s *must* make bye-laws for common lodging-houses, and all urban S.A.s for slaughter-houses.)

Regulations.

Regulations differ from bye-laws only in not requiring confirmation by the L.G.B.

The following are the chief *regulations* S.A.s are empowered to make:—

(*a*) Mode of communication between sewers and drains.
(*b*) Removal and detention of ship-borne infectious cases.
(*c*) Mortuaries.
(*d*) Dairies, cowsheds and milk-shops.

In dealing with sanitary law in this chapter, the enactments will not be summarised individually. A list of *legal definitions* will first be given, followed by seventeen headings of sanitary subjects; and under each heading extracts will be given from the various laws which concern that subject.

LEGAL DEFINITIONS.

Ashpit.

Means any ashtub or receptacle for the deposit of fæcal matter or rubbish.

Common Lodging-house.

A lodging-house where poorer classes are received for short periods in a common room.

Contributory Place.

A parish, or part of a parish, in a *rural* district charged with the expense of sanitary work in that district.

(N.B.—In *urban* districts a general borough rate is charged.)

Curtilage.

"A courtyard, back, side or piece of ground lying near to a dwelling-house."

Drain.

A conduit receiving the drainage of one building only, or of premises within the same curtilage.

Nuisance.

(*a*) *At Common Law.* "Anything which worketh hurt, inconvenience or damage to any one" (Blackstone).

(*b*) *By Statutory Law.* "Something which either actually injures or is likely to injure health, and admits of a remedy, either by the individual whose act or omission causes the nuisance, or by the local authority" (Wynter-Blyth).

Overcrowded.

Less than 400 cub. ft. per person, if for living *and* sleeping; or 300 cub. ft. if for living only.

Sewer.

Includes sewers and drains of all kinds, except drains as aforesaid.

Street.

Includes any highway (not being a turnpike road), and any public bridge (not being a county bridge), and any road, lane, footway, square, court, alley or passage, whether a thoroughfare or not.

Underground Room.

A room with a floor more than 3 ft. below the footpath.

SANITARY SUBJECTS.

I. Bakehouses.

Factory and Workshops Act, 1901.

Sanitary inspection under local S.A., unless mechanical, when it will be under Factory Inspector.

Must not be let or occupied unless—

(*a*) No w.c., privy or ashpit in direct communication.
(*b*) Water cisterns separate from any w.c. cistern.
(*c*) No opening from sewer drain within the bakehouse.

It must be—

(*a*) Oil-painted or varnished every seven years, and
(*b*) Washed with hot water and soap every six months, or
(*c*) Lime-washed every six months.
(*d*) Not underground.
(*e*) Not in communication with any sleeping-room on same floor in same building.

II. Canal Boats.

Canal Boats Acts, 1877 *and* 1884.

Cannot be occupied unless registered. Number of occupants, age and sex to be specified. Registration with S.A. abutting on canal. Certificate to owner and one to master. Must be lettered, unaltered, and marked "Registered."

Infectious diseases to be notified by master to S.A.

Regulations of 1878.

(*a*) One dry weather-proof cabin.
(*b*) After-cabin to have minimum 180 cub. ft.
(*c*) Fore-cabin to have minimum 80 cub. ft.
(*d*) Adequate ventilation and sleeping accommodation.
(*e*) Storage for three gallons water.
(*f*) Double bulkhead.
(*g*) Sexes to be separate.

(*h*) Cabins clean, and painted every three years.
(*i*) Bilge-water pumped out daily.
(*j*) Master to notify infectious disease at once.
(*k*) S.A. to make annual report to L.G.B.

III. **Cellar Dwellings.**

Public Health Act, 1875.

Person sleeping constitutes "dwelling."
Existing dwellings:—

(*a*) Height 7 ft., with 3 ft. above street level.
(*b*) Open area along frontage $2\frac{1}{2}$ ft. wide, and 6 ins. below floor.
(*c*) Must have closet and ashpit accommodation.
(*d*) Must have fire-place.
(*e*) External window 9×9 ins., made to open.
(*f*) No steps over or across the window.

Public Health (London) Act, 1891.

Bed—presumptive evidence.
Clauses *as above, except*:—

1. Walls to have damp-proof course.
2. Area to be 4 ft. wide.
3. Drains under room to be gas-tight.
4. Windows to be $\frac{1}{10}$ floor space.

IV. **Cemeteries.** See Chapter XVI.

V. **Common Lodging-houses.**

Public Health Act, 1875.

(*a*) To be inspected, approved and registered by S.A.
(*b*) Registration notice to be prominently fixed outside.
(*c*) S.A. to enforce water supply at reasonable cost.
(*d*) Walls and ceilings whitewashed, April and October.
(*e*) Returns of vagrants to be made.

Model Bye-laws.

(*a*) 300 cub. ft. per head (two children = one adult).
(*b*) None over ten to be with opposite sex.
(*c*) Rooms for married couples if beds screened.
(*d*) Yards and courts to be kept clean.
(*e*) Floors swept daily and washed weekly.
(*f*) Closets clean and efficient.
(*g*) No wet refuse in ashpits.
(*h*) Beds clean and aired one hour daily.
(*i*) Windows opened one hour daily.
(*j*) Basin and clean towels.
(*k*) Slops removed before 10 a.m.
(*l*) Infectious cases reported to M.O.H.

VI. **Dairies.**

Dairies, Cowsheds and Milk-shops Order, 1885.

(*a*) Cow-keeper, dairyman and purveyor to be registered.
(*b*) L.A. to see to lighting, ventilation, air space, etc.
(*c*) Infectious diseases kept apart from trade.
(*d*) No w.c. to communicate with milk-shop or dairy.
(*e*) No one to sleep in milk-shop.
(*f*) No swine in cowshed.
(*g*) L.A. may make regulations.

Model regulations.

(*a*) *Cowsheds.*

M.O.H. or I.N. may inspect.
Well lighted.
Wholesome air, 800 cub. ft. per head.
Clean interior.
Whitewashed May and October.
Floor cleaned daily.
Drain to outside gully.
Clean water supply provided.

(*b*) *Dairies.*

Well lighted and ventilated.
Floor washed once daily.
Drain to outside gully.
Adequate supply of good water.

(*c*) *Milk-shops.*

Vessels cleaned with steam or boiling water after use.
Prevent exposed milk from contamination.
Milk not to be deposited in—

(*a*) Room with impure air.
(*b*) Kitchen or living-room.
(*c*) Sleeping-room.
(*d*) Room with inlet to drain.

VII. **Drainage.**

Public Health Act, 1875 (*and Public Health* (*Scotland*) *Act*, 1897).

All sewers under the S.A.
S.A. must provide sufficiency of drainage and sewerage.
Drains must be well constructed.
Drainage compulsory in every house.
S.A. may settle material, size and levels.
Drain must lead to public sewer if within 100 ft.
For sewage:—S.A. may construct works.
„ „ purchase or lease land.
„ not to cause nuisance.
„ to purify sewage before discharge.

Model Bye-laws.

Damp sites must be drained.
Rain-pipes for rain-water.
Lowest storey must be above sewer.

Drains: 4 ins. diameter: impervious: good joints: proper fall: laid in concrete.
Drain inlets must be trapped.
No drain under building unless in 6 ins. concrete.
Drains must be ventilated each side of building.
Main drain trapped within curtilage.
Branch drains must join obliquely.
Inspection chamber on house side of main trap.
No house-drain inlet except w.c.
Soil-pipe, 4 ins.: outside house: ventilated upwards.
No trap between soil-pipe and drain.
Waste-, sink-, and bath-pipes into open air, over trapped gully.

VIII. **Factories.**

Factories and Workshops Acts, 1878, 1883, 1891 and 1895.

(A workshop with mechanical power is called a factory.)

Factories are under the Home Office; workshops under S.A.

Factory must be :—
- Clean.
- Free from offensive smell.
- Not overcrowded —250 cub. ft. per head; 400 cub. ft. per head overtime.
- Permissible numbers to be posted.
- Reasonable temperature.
- Ventilated.

Special rules for dangerous occupations.
Walls and ceilings whitewashed every fourteen months.
Separate closet accommodation for each sex.
F.I. to report sanitary defects to S.A.

List of outworkers to be kept.
No outwork in house where small-pox and scarlet fever may be.
Practitioner attending Pb., P., As. or Anthrax to notify C.F.I. (Fee 2*s.* 6*d.* Penalty 40*s.*)
M.O.H. must notify F.I. of child under 14, or young person of 14 to 18, or woman, employed in any workshop.

IX. **Food Supply.**

Public Health Act, 1875.

M.O.H. (or I.N.) may inspect and examine at reasonable times, including Sundays, articles of food exposed for sale.
Articles so seized, if unsound, may be condemned by order of the justice.
People preventing M.O.H. from entering—penalty £5.
(N.B.—Eggs, butter and cheese not specifically mentioned—no proceedings if already sold.)

Public Health (Amendment) Act, 1890.

The 1875 Act extended to *all* articles intended for food of man and *sold* or exposed for sale.

Margerine Act, 1887.

Must be legibly so marked.
Manufactories must be registered.

Public Health (London) Act, 1891.

M.O.H. or S.I. may enter any premises and examine any animal and any article, solid or liquid.

Sale of Horseflesh Act, 1889.

Must have 4-in. letters :—" Horseflesh is sold here."

Sale of Foods and Drugs Act, 1875.

Not to mix or treat any article of food or drug so as to render injurious. Penalty £50.
Not to sell food or drug not of nature, quality and substance asked for.
Public Analysts appointed.
Private individual may purchase food or drug, and have analysed at fee not exceeding 10*s*. 6*d*.

Sale of Foods and Drugs (Amendment) Act, 1879.

Adulterated or impoverished butter, milk, cream or food, if imported, £20 fine.
Commissioner of Customs takes samples: $\frac{1}{3}$ self, $\frac{1}{3}$ importer, $\frac{1}{3}$ analyst.
L.G.B. and B.Agric. (in interests of consumer and agric.) may procure samples—divided in 4 parts (3 as above and 1 to the Board).
L.A. to appoint Public Analyst.
B.Agric. to make regulations for analysis of milk, cream, butter, cheese.
Margarine not to contain more than 10% butter fat.
Milk sold from vehicle must have name and address on cart.
Obstructing inspector—gratuity—bribe—fine, £20.
Brandy, whisky and rum must not be watered below 25° under proof; gin 35°.

X. **Housing of Poor.**

Housing of Working Classes Act, 1890.

1. *Unhealthy urban districts.*

(*a*) Official representation by M.O.H.: (1) for himself; (2) by two J.P.s; (3) by 12 ratepayers.
(*b*) This is considered by S.A.
Improvement scheme passed.

(*c*) Notice in local papers, and notice to interested persons.
(*d*) Petition from S.A. to confirming authority, and local inquiry by them.
(*e*) Provisional order.
(*f*) Introduced as parliamentary bill.

In less extensive matters than above we have :—

2. *Unhealthy rural and urban dwellings.*
(*a*) M.O.H. or 4 or more inhabited householders report.
(*b*) S.A. inspects.
Owner compelled to improve, or J.P.'s closing order.
(*c*) Confirmation by provisional order of L.G.B.
(*d*) Goes to Parliament only if opposed.

XI. **Infectious Disease.**

See Chapter XVII.

XII. **New Buildings and Streets.**

Public Health Act, 1875.

Public streets vested in S.A.
S.A. to level, pave and repair as required.

Model Bye-laws.

Streets must be 42 ft. wide.
Streets must be open at one end.
Sites must be concreted 6 ins., and not on polluted soil.
New buildings to be of hard and incombustible material, with damp-proof course.
If of more than 2 storeys, wall must be 13½ ins. thick below topmost storey, and 9 ins. thick above.
If the building be *longer* than 35 ft., then it must be 18 ins. thick for one storey.

Party-walls to be 15 ins. above roof.
Roofs to be incombustible, and with rain-gutters.
House must have open space in front of 24 ft. (including street).
In rear must have open space of 150 sq. ft.
Each habitable room must have external windows, $\frac{1}{10}$th floor area. Also fire-place or ventilating shaft.
Plans and sections of new streets, buildings or alterations must be submitted to S.A.

XIII. **Nuisances.**

Public Health Act, 1875.

Premises Sanitary conveniences Animals Deposits	if nuisance or injurious to health	may be dealt with summarily.
House overcrowded Factory or workshop overcrowded Smoking chimneys		

Housing of Working Classes Act, 1885.
Tents, sheds, vans dirty or overcrowded.

Quarry Fencing Act, 1887.
Unfenced quarries 50 yds. from public highway.

Coal Mines Regulation Act, 1887.
Unfenced abandoned coal mines.

Public Health (Scotland) Act, 1897.
Injurious well or water supply.
Overcrowded cemeteries.

Public Health (London) Act, 1891.
Absence of prescribed water fittings.
Foul pools or ditches.

Procedure for abating.

Started by :—Aggrieved person, or
2 householders, or
S.A. officer, or
Relieving officer, or
Any police officer.

Then :—

Intimation Notice from M.O.H. or S.I.

On non-compliance :—

Statutory Notice served by S.A.

On further non-compliance :—

S.A. applies to Justice for summons.

Court then makes :—

Nuisance Order for abatement, prohibition or closure.

XIV. **Offensive Trades.**

Public Health Act, 1875.

1. Blood boiler 2. Bone boiler 3. Fell-monger 4. Soap boiler 5. Tallow melter 6. Tripe boiler	must not be established without consent of Urban S.A. S.A. may make bye-laws.

Model Bye-laws.

7. Blood drier 8. Leather dresser 9. Tanner 10. Fat melter 11. Glue maker 12. Size maker 13. Gut scraper	added to above list.

(*a*) Material not for immediate use to be carefully stored.
(*b*) Take best means to deprive vapours of noxious or injurious properties.
(*c*) Provide efficient and *cold* drainage.
(*d*) Clean floors once daily.
(*e*) Walls scraped and whitewashed twice yearly.
(*f*) Apparatus to be kept clean.
(*g*) Waste lime to be removed at once.
(*h*) Soaking tanks to be often cleaned.
(*i*) Free access for inspection by M.O.H., I.N., S.A.

XV. **River Pollution.**

Rivers Pollution Prevention Act, 1876.

Sources of pollution :—

1. Solids from factories, etc.
2. Sewage effluents (untreated)
3. Mining effluents

} forbidden.

Proceedings instituted on *sewage* pollution by :—

(*a*) Any private person.
(*b*) Aggrieved S.A.

Manufacturing and *Mining* effluents :—
S.A. only acts on approval of L.G.B.

XVI. **Sanitary Conveniences.**

Public Health Act, 1875.

Unlawful to build without enough closet accommodation.
Separate w.c.s for sexes in factories.
Urban S.A.s may provide public conveniences.
All S.A.s *must* see drains are well made and kept.
On written application S.A. may investigate premises to see nuisance.

Public Health (London) Act, 1891.

New house to have enough w.c.s with proper accessories.

Model Bye-laws.

W.c.s to have window 2′ × 1′ clear of frame.
„ must adjoin external wall.
„ „ have separate cistern, 3 gals.
„ „ „ non-absorbing conical basin.
„ D traps forbidden.
Privy capacity not to be more than 3 months.
„ to be convenient for scavenging.
Cesspools 50 ft. from houses.
„ 100 ft. from water supply.
„ must *not* connect with sewer.
Ashpits 6 ft. from houses.
„ 50 ft. from water supply.
„ to be easy for scavenging.
„ to be of only one week's capacity.
„ walls to be impervious, and above ground level.

XVII. **Scavenging.**

Public Health Act, 1875.

S.A. may (or by L.G.B. *must*) contract for scavenging.
M.O.H. or two practitioners certifying a house to be filthy, the S.A. may order the occupier to clean.

Public Health (London) Act, 1891.

S.A. must clean streets, footpaths, cesspools, etc.
S.A. must remove house refuse at proper intervals.
S.A. may undertake collection of manure.

Model Bye-laws.

Private Scavenging (where S.A. do not undertake).
Occupier to clean front premises daily, except Sunday.
Occupier to remove house refuse weekly.
" " " excreta at regular intervals.

Urban, to prevent nuisances.

Occupier to clear snow.
No filth within 100 yds. of street for more than 24 hours.
No swine within 100 ft. of dwelling.

XVIII. Slaughter-houses.

Public Health Act, 1875.

1. Must be licensed.
2. Must be registered.
3. Notice to that effect conspicuously placed.

Model Bye-laws.

(*a*) Must be 100 ft. from dwelling.
(*b*) Approach not through a shop.
(*c*) Free ventilation.
(*d*) No living-room above.
(*e*) Separate pens for cattle.
(*f*) Good water supply.
(*g*) Tank 6 ft. above floor.
(*h*) Paved with asphalte or concrete.
(*i*) Proper slope to floor.
(*j*) Drainage to trapped gully *in open air.*
(*k*) Walls cemented to height of 7 ft.
(*l*) No w.c. or cesspool in the slaughter-house.
(*m*) Offal removed in 24 hours.
(*n*) No dogs allowed in slaughter-house.

XIX. **Water Supply.**

Public Health Act, 1875.

S.A. may construct, hire, purchase or contract for works.

S.A. may acquire land and borrow money.

Water must be pure and wholesome.

S.A. may charge water-rates.

S.A. *must* control gratuitous water supplies.

If water bad or S.A. neglects—complain to L.G.B.

Public Health (Water) Act, 1878.

Rural S.A. *must* see occupied houses have enough good water.

If not, notice sent by S.A., and again after 6 months.

Owner may address memorial

(*a*) Supply not required, or

(*b*) Not given enough time, or

(*c*) Cost too high.

Public Health (London) Act, 1891.

Absence of proper water supply is a nuisance.

" " " " renders house uninhabitable.

S.A. certificate necessary before house can be occupied.

If water company cut off water, they must notify S.A. in 24 hours.

Public Health (Scotland) Act, 1897.

Injurious or dangerous well, or water, is nuisance.

Occupation of house cannot be stopped owing to improper water supply.

CHAPTER XX

SANITARY ADMINISTRATION

THE care of the Public Health, Registration of Births and Deaths, Baths, Artisans' Dwellings, Prevention of Disease, etc., etc., was formerly under the tripartite control of the Home Secretary, Poor Law Board, and the Privy Council.

The whole of this sanitary supervision was, by the Public Health Act of 1875, entrusted to the Local Government Board (L.G.B.) which had been established in 1871.

There is also a L.G.B. for Ireland, and a L.G.B. for Scotland, who control the Public Health of those countries.

By the Public Health Act, 1875, the L.G.B. may constitute any S.A. whose district abuts on a port, as a *Port Sanitary Authority.*

Under the Local Government Act, 1894, England and Wales is divided into :—

(*a*) *Administrative Counties* including—
  (1) *Urban Districts.*
  (2) *Rural Districts* and
(*b*) *County Boroughs.*
(*c*) *Municipal Boroughs.*

The S.A. for County is the "County Council" (by Local Government Act, 1888).

The S.A. for Urban Districts is the "Urban District Council."

The S.A. for Rural Districts is the "Rural District Council."

The S.A. for County Boroughs is the "Town Council."

The S.A. for Municipal Boroughs is the "Municipal Council."

Powers and Duties of Local Authorities.

I. *County Councils.*

(*a*) Supervision of town, municipal, urban district, and rural district councils.
(*b*) Appointment of county M.O.H.
(*c*) Receipt of reports from county and district M.O.H.
(*d*) Contribution to salaries of health staff.
(*e*) Appointment of analysts.
(*f*) Making of bye-laws for—
  (1) Supervision of county (confirmed by Secretary of State).
  (2) Prevention of nuisances (confirmed by L.G.B.).
(*g*) Prevention of river pollution.
(*h*) Arrangement of hospital districts.
(*i*) Acquirement of land for allotments.
(*j*) Loaning of money for isolation hospitals.
(*k*) Reporting to L.G.B. on all public health matters.

II. *County Boroughs.*
Municipal Boroughs.
Urban District Councils.

(*a*) Appointment of M.O.H., I.N., and Surveyor.
(*b*) To form committees.
(*c*) To license and control knackers' yards.
(*d*) To get powers of Parish Councils from L.G.B.
(*e*) To adopt adoptive acts.
(*f*) To administer acts:—
Public Health Act, 1875.

Public Health (Amendment) Act, 1890.
Public Health (Water) Act, 1878.
Rivers Pollution Prevention Acts, 1876 and 1893.
Factory and Workshops Act, 1901.
Housing of the Working Classes Acts, 1890 and 1899.
Infectious Diseases Notification Acts, 1889 and 1899.
Infectious Diseases Prevention Acts, 1890.
Sale of Food and Drugs Acts, 1875, 1879 and 1899.
Horseflesh Act, 1889.
Margarine Act, 1889.
Dairies, Cowsheds and Milkshops Orders, 1885 and 1899.
Public Health (Interments) Act, 1879.
Canal Boats Acts, 1877 and 1884.
Infant Life Protection Act, 1897.

III. *Rural District Councils.*
(*a*) To hold land.
(*b*) To license and control knackers' yards.
(*c*) To appoint "parochial committees."
(*d*) To delegate powers to "parish councils."
(*e*) To administer acts as in (II).
(N.B.—There are restricted powers in parts of Public Health Acts and Housing of the Working Classes Acts.)
(*f*) May be invested with powers of urban district council in certain cases, if permitted by L.G.B.

MEDICAL OFFICERS OF HEALTH.

Under the Towns Improvement Clauses Act of 1847 Liverpool appointed an M.O.H.

By a special Act London also appointed one in the following year.

In 1848 the Public Health Act allowed local boards to appoint qualified practitioners as M.O.H.

The Public Health Act of 1872 imposed this duty on the S.A.

The Local Government Act, 1888, requires (after January 1892) that an M.O.H. of a district of 50,000 inhabitants must have a D.P.H., or must have been M.O.H. for three previous years to a district of 20,000 or more, or have been three years on the L.G.B. as a medical inspector.

Every M.O.H. holding his appointment subject to the approval of the L.G.B. must forward copies of his annual and special reports to the Board.

The **duties of an M.O.H.** are laid down by an L.G.B. order of March 23, 1891, and are as follows:—

To:—

1. Inform himself as to influences affecting or threatening the public health.
2. Inquire into and ascertain the causes, origin and distribution of disease in his district, and to find to what extent it can be removed or mitigated.
3. Inspect systematically and occasionally, to discover injurious conditions.
4. Advise S.A. on all health matters, and give certificates in all necessary cases.
5. Advise S.A. in health matters, reframing and working of bye-laws.
6. Pay an immediate visit to cases of infectious disease, and take such action as may be necessary.
7. Superintend the I.N.'s work, and take steps on his request.
8. Inspect any food exposed for sale if he finds necessary, or is directed by S.A., and take steps to have same dealt with by a justice.
9. Perform duties imposed on him by bye-laws and regulations.

10. Inquire into offensive trades in his district, and report on means for prevention of nuisance.
11. Attend at stated times at office of S.A.
12. Send casual written reports to S.A. as to requirements for improvement or protection of health, and as to the sickness or mortality in the district.
13. Keep books (provided by S.A.), with entry of visits, observations, instructions, date and nature of applications, date and result of action taken, and produce such books on request of S.A.
14. Furnish an annual report including:—
    (*a*) Summary of action taken during year.
    (*b*) Sanitary state of district.
    (*c*) Inquiries held.
    (*d*) Legal proceedings taken.
    (*e*) Supervision exercised.
    (*f*) Tabular and classified statements as to sickness and mortality.
15. Give immediate information to L.G.B. of any dangerous epidemic.

    Send copies of annual and special reports to L.G.B.

    Give special report to L.G.B. of closure of schools advised by him.
16. Furnish similar reports to the County Council.
17. Carry out special instructions issued by L.G.B., or lawful orders of S.A.
18. Observe regulations made by L.G.B., under Sec. 134 of Public Health Act, 1875.

Routine work of Medical Officers of Health. (After Wilson.)

(*a*) *Natural condition.*

Information can be got from geological maps of Ordnance Survey.

Map of district (large scale) is necessary.

Town maps should show main sewers, water mains, and ward divisions.

Meteorological conditions should be obtained weekly through S.A.

If such observations are not made, it is not part of his duty to supply the deficiency, but it would be certainly better for him to take them.

(*b*) *Dwellings.*

Sanitary condition of all districts is found by inspections of S.I.s, and should be known by M.O.H.

Houses deemed unfit for habitation are reported by M.O.H. under Housing of the Working Classes Act, 1890.

Common lodging-houses, cellar dwellings, schools, and slummy areas should be frequently visited.

(*c*) *Factories, workshops, bakehouses, slaughter-houses, cowsheds, dairies,* and *offensive trades,* require constant supervision. M.O.H. should be satisfied that bye-laws are carried out.

(*d*) *Water.*

Quality and amount per head should be known to M.O.H., also risks of pollution, situation of wells, etc.

(*e*) *Drainage.*

Information can be obtained from borough engineer or town surveyor.

Attend to ventilation and flushing of sewers.

(*f*) *Scavenging.*

Periodical personal inspection advisable.

(*g*) *Legal proceedings.*

M.O.H. should not himself conduct cases, which is the duty of the clerk to S.A. or the S.I.

M.O.H. will have to give certificates or evidence when required.

(*h*) *Statistical returns.*

District Registrars forward returns of births and deaths to M.O.H. weekly—or infectious deaths at once.

M.O.H. should get full particulars as to statistics of his district from past annual reports, census, etc.

Workhouse medical officers furnish M.O.H. with returns of sickness, deaths, or infectious diseases.

(*i*) *Routine duty.*

M.O.H. should attend at office at stated hours every morning to examine books of S.I. and give instructions, also to hear complaints.

There will also be special and periodical inspections, inquiries, attendances at meetings and legal proceedings.

M.O.H. should keep a diary, a complaint book, inspection book, infectious diseases book, and birth and death returns book.

(*j*) *Annual Reports.* (After Hamer.)

The Local Government Board has from time to time issued Memoranda (with appended explanatory tabular forms) concerning the preparation of annual reports. It has been pointed out by the Board that the report should, in order to secure uniformity, be in all instances for the year ending December 31, and that it should be completed, if possible, within six weeks, and at latest within three months, of the end of the year to which the report relates. The following paragraphs may be quoted from the Memorandum of 1901:—

"The report should be chiefly concerned with the conditions affecting health in the district, and with the means for improving those conditions. It should contain an account, brought up to the end of the year under review, of the sanitary circumstances of the district, and of any improvement or deterioration

which may have occurred during the year in these circumstances."

As subjects concerning which the Board desire to obtain information the following deserve to be borne in mind :—

"Physical features and general character of the district.

> "House accommodation, especially for the working classes: its adequacy and fitness for habitation. Sufficiency of open space about houses, and cleanliness of surroundings. Supervision over erection of new houses.
>
> "Sewerage and drainage: its sufficiency in all parts of the district. Conditions of sewers and house drains. Method or methods of disposal of sewage. Localities where improvements are needed.
>
> "Excrement disposal: system in vogue; defects, if any.
>
> "Removal and disposal of house refuse—whether by public scavenger or occupiers: frequency and method.
>
> "Water supply of the district or its several parts: its source (from public service or otherwise), nature (river water, well water, upland water, etc.), sufficiency, wholesomeness and freedom (by special treatment or otherwise) from risks of pollution.
>
> "Places over which the Council have supervision, *e.g.* lodging-houses, slaughter-houses, bakehouses, dairies, cowsheds and milkshops, factories and workshops, and offensive trades.
>
> "Nuisances: proceedings for their abatement—any remaining unabated.
>
> "Methods of dealing with infectious diseases: notification; isolation hospital accommodation and its sufficiency; disinfection."

"The medical officer of health, in reporting his proceedings and advice, should put on record whether he has made systematic inspections of his district. By 'systematic inspections' are meant inspections independent of such inquiries as the medical officer of health may have to make into particular outbreaks of disease, or into unwholesome conditions to which his attention may have been specially called by complaints or otherwise, and such inspections will include the house-to-house inspections which may be necessary in particular localities.

"In making such systematic inspections, as in much of his other action, the medical officer of health will usually have required the assistance of the inspector of nuisances, and the medical officer should include in his report an account of the action which, at his instance, the inspector may have taken for the removal of nuisances injurious to health.

"The tabular statements of sickness and mortality in the district during the year, to be made on the forms supplied for the purpose, should be the subject of comment in the text of the report, in so far as deductions from them may assist the Board and the Councils concerned to an appreciation of the lines of action needful in the future."

DUTIES OF SURVEYORS.

Urban S.A.s must appoint a town surveyor, under Public Health Act, 1875, or rural authorities with urban powers.

No L.G.B. orders have been issued as to surveyor's duties.

He will have to know something of architecture, surveying, water and sanitary engineering.

It is better that he should have passed some examination, such as that of the Sanitary Institute, and he

should be well acquainted with *The Annotated Building Bye-Laws* (Knight and Co.).

DUTIES OF SANITARY INSPECTORS.

In England and Wales they are still called by the objectionable title "Inspector of Nuisances," given by the Public Health Act, 1875.

By the Public Health (London) Act, 1891, and the Public Health (Scotland) Act, 1897, they are called "Sanitary Inspectors," and by the Public Health (Ireland) Act, 1878, they are styled "Sanitary Sub-officers."

Orders issued by L.G.B., 1891.

1. To perform his duties under the Public Health Act, 1875, under special directions of S.A. or M.O.H.
2. Attend meetings of S.A. if required.
3. Periodical inspections to find nuisances.
4. On receiving notice of nuisance, to visit spot as soon as possible.
5. Report to S.A. offensive trades and breach of their bye-laws.
6. Report to S.A. damage to, waste or fouling of, water supply.
7. Periodical visits to food-shops. If unfit for food, seize and take proceedings, or report to M.O.H.
8. If directed by S.A., procure samples of food or drugs for analysis by Public Analyst.
9. To give immediate notice to M.O.H. of infectious disease or overcrowding.
10. To obey M.O.H. (subject to S.A.) in measures for preventing spread of infectious disease.
11. To keep daily "inspection" book and book with particulars of sanitary condition of premises in respect of which action has been taken.

12. Must produce books to M.O.H.
13. Must superintend works for suppression of nuisances if required by S.A.
14. Act under Contagious Diseases (Animals) Act, 1886, if required by S.A.
15. To follow lawful orders of S.A., or applicable orders of L.G.B.

TROPICAL ORGANISATION.

A good model is that of the United States in their colony of the Philippine Islands.

There is a *Bureau of Public Health*, which is organised into eleven divisions, each division under an officer qualified for the position he occupies.

1. Statistics, reports and medico-legal.
2. Inspection and municipal pharmacies.
3. Leper colony.
4. Infectious diseases hospitals.
5. Vaccination.
6. Veterinary.
7. Sanitary engineering.
8. Disbursements.
9. Property accountability.
10. Clerical.
11. Provincial sanitation.

The chief of each division is held accountable for the working and results of his division.

APPENDIX

Candidates wishing to obtain special qualifications in Public Health may do so by either obtaining a *degree* or a *diploma*.

By the Act of 1886 a D.P.H. can be instituted "if the said Diploma appears to the Privy Council or to the General Medical Council to deserve recognition in the Medical Register." Thus universities and examining bodies are obliged to conform to the requirements of the General Medical Council in regard to Public Health Examinations, which tends to produce uniformity of standard.

Examinations differ slightly, however, in special characteristics.

For instance, the Oxford examination often lays special stress on Chemical work, the Cambridge on Bacteriology, the London Conjoint on Physics, and so on.

The following are the chief **Degrees** in State Medicine:—

(1) *London University.*

M.D. (State Medicine).

(Must be M.B., B.S., Lond., and subsequently had the same training required for D.P.H. diplomas.)

(2) *Edinburgh and Glasgow Universities.*

B.Sc. (Public Health).

(Must be medical graduate of recognised university.)

D.Sc. (Public Health).

(B.Sc. five years—Thesis.)

(3) *Durham University.*

B.Hy.

(Must be medical graduate of recognised university.)

D.Hy.

(4) *Victoria (Manchester) and Birmingham Universities.*

B.Sc. (Public Health).

(5) *Indian Universities.*

L.S.Sc.—Licentiate in Sanitary Science.

(This is a degree given in open convocation by the Universities of Calcutta, Bombay and Madras.)

Diplomas in Public Health (**D.P.H.**) are given by the following universities and examining bodies—

Conjoint Boards in England, Scotland and Ireland.

Universities—

Oxford,
Cambridge,
Dublin,
Royal (Ireland),
Aberdeen,
St. Andrews,
Liverpool,
Durham,
Victoria (Manchester),
Birmingham,
Leeds,
Sheffield.

The requirements of the General Medical Council as regards the special education and examination of candidates for registrable diplomas and degrees in State Medicine are as follows—

Rule 1.—A period of not less than twelve months

shall have elapsed between the attainment of a registrable qualification in medicine, surgery, and midwifery, and the admission of the candidate to any examination, or any part thereof, for a Diploma in Sanitary Science, Public Health, or State Medicine.

Rule 2.—Every candidate shall have produced evidence that, after obtaining a registrable qualification, he has during six months received practical instruction in a laboratory or laboratories, British or foreign, approved by the Licensing Body granting the diplomas, in which Chemistry, Bacteriology, and the Pathology of the diseases of animals transmissible to man are taught.

Rule 3.—Every candidate shall have produced evidence that, after obtaining a registrable qualification, he has during six months (of which at least three months shall be distinct and separate from the period of laboratory instruction required under Rule 2) been diligently engaged in acquiring a practical knowledge of the duties, routine and special, of Public Health Administration, under the supervision of—

(*a*) In England and Wales, the Medical Officer of Health of a county or of a single sanitary district having a population of not less than 50,000 or a Medical Officer of Health devoting his whole time to Public Health work; or

(*b*) In Scotland, a Medical Officer of Health of a county or counties, or of one or more sanitary districts having a population of not less than 30,000; or

(*c*) In Ireland, a Medical Superintendent Officer of Health of a district or districts having a population of not less than 30,000; or

(*d*) In the British Dominions outside the United Kingdom, a Medical Officer of Health of a sanitary district having a population of not less than 30,000, who himself holds a registrable diploma in Public Health; or

(*e*) A Medical Officer of Health who is also a teacher in the department of Public Health of a recognised medical school; or

(*f*) A Sanitary Staff Officer of the Royal Army Medical Corps having charge of an army corps, district, or command, recognised for this purpose by the General Medical Council.

NOTE (1).—The certificate of an Assistant Medical Officer of Health of a county or of a single sanitary district having a population of not less than 50,000 may be accepted as evidence under Rule 3, provided the Medical Officer of Health of the county or district in question permits the assistant officer to give the necessary instructions and to issue certificates.

NOTE (2).—Provided that the period of six months may be reduced to a period of three months (which shall be distinct and separate from the period of laboratory instruction required under Rule 2), in the case of any candidate who produces evidence that, after obtaining a registrable qualification, he has during three months attended a course or courses of instruction in sanitary law, sanitary engineering, vital statistics, and other subjects bearing on Public Health Administration, given by a teacher or teachers in the Department of Public Health of a recognised medical school.

NOTE (3).—A candidate who shall have produced evidence that he has himself held for a period of not less than three years an appointment as Medical Officer of Health of a sanitary district within the British Dominions, and having a population of not less than 15,000, may be exempted from the requirement of Rule 3.

Rule 4.—Every candidate shall have produced evidence that, after obtaining a registrable qualification, he has attended during three months the practice of a hospital for infectious diseases at which opportunities are afforded for the study of methods of administration.

NOTE (1).—Methods of administration shall include the methods of dealing with patients at their admission and discharge, as well as in the wards, and the medical superintendence of the hospital generally.

NOTE (2).—In the case of a Medical Officer of the Royal Army Medical Corps a certificate from a Principal Medical Officer under whom he has served, stating that he has during a period of at least

three months been diligently engaged in acquiring a practical knowledge of hospital administration in relation to infectious diseases, may be accepted as evidence under Rule 4.

Rule 5.—The examination shall have been conducted by examiners specially qualified; it shall have extended over not less than four days, one of which shall have been devoted to practical work in a laboratory, and one to practical examination in, and reporting on, subjects which fall within the special outdoor duties of a Medical Officer of Health.

The Rules 2, 3, 4, as to study, shall not apply to medical practitioners registered or entitled to be registered on or before January 1, 1890.

The subjects in which a candidate must qualify himself for examination, the courses of study he must follow, whatever the State Medicine diploma in view, are indicated by the foregoing rules; all the examining bodies necessarily insist upon compliance with them on the part of their candidates. Each examining body issues a detailed schedule of the subjects of examination, which can be obtained by intending candidates on application to the dean of the medical faculty.

The following are a few sample examination papers.

London M.D. (State Medicine).

Case in State Medicine.

In the autumn of 1880 an epidemic of enteric fever, preceded and accompanied by prevalence of diarrhœa, took place at G, a seaside health-resort having a resident population of about 10,000, and an annual average of 1000 visitors.

At first the outbreak was limited to a small area A, in the older part of the town. Between September 10th and September 17th seven houses in this area were invaded, eight inmates being attacked; and between September 17th and October 12th seven other inmates

of the same houses fell ill. These fifteen cases were all that were heard of in this part of the town, but from the middle of October onwards the epidemic assumed larger proportions, without evidence of localisation in any particular neighbourhood. The earliest recorded attack outside the area A began about October 15th, and two others, in one house, occurred on the 18th. Up to the end of October there had been 60, including the 15 in A. In the first week in November there were 213 attacks, but after this the numbers rapidly declined, and after the 10th no further houses were invaded, although, until the end of the month, a few new cases continued to occur in premises already implicated.

In all, 315 attacks of enteric fever and 33 deaths became known to the authorities. They occurred in 178 houses, which, as already mentioned, were scattered about the town, except for the early incidence upon A. As regards age and sex, their distribution was as follows—

		0–10	10–20	20–40	Over 40	Total.
Attacked . . .	Male .	24	55	64	4	147
	Female	28	61	70	9	168
	Total .	52	116	134	13	315

This list includes all the cases which were pronounced by the medical attendants to be enteric fever. Some of them were slight, and the character of the epidemic generally was not virulent. From August to November (that is, before and during the enteric fever epidemic) there was widespread prevalence of diarrhœa, affecting adults as well as children. No numerical estimate can be given of the attacks of this kind, but they caused

few deaths, and, while distributed over the district generally, they were thought to have had an especial incidence upon those houses in which cases of enteric fever occurred.

G was, in 1880, a Local Board District. There was no hospital for the isolation of infectious diseases, nor was there any local Act in force bearing upon sanitary administration. The town stands upon a plateau of loam about 15 ft. deep, resting on the chalk. The w.c. system was in almost universal use, but the flush was obtained direct from the mains.

The town was sewered, the sewage being discharged into the sea for three hours during each tide. In the intervals the outfall was blocked. The sewers were, for the most part, ventilated, but in the older parts of the town, including A, this was not the case.

The sanitary conditions (so far as the construction and drainage of houses, and the arrangements for refuse disposal, are concerned) were, on the whole, satisfactory, but in the older portions there were many defects, and in the area A especially the houses were damp, and the house-drains were for the most part defective, and rarely disconnected from the sewer. In this part also the w.c. soil-pipes were inside the house, and, as a rule, unventilated.

Nearly all the town was supplied with water from the mains, the ultimate sources being deep wells in the chalk. Chemical analysis, made before, during and after the epidemic, revealed no deviation from the usual standard of purity. A few old pumps in the town remained in use, chiefly for washing purposes, and one of these stood in the yard at the back of a dairy Z, which was situated in the old part of the town outside the area A. This pump was connected with a well beneath, which supplied the drinking-water of an adjoining house Y, but in the dairyman's house, Z, the pump-water was used only for washing and rinsing

the cans, town water from the mains being employed for drinking purposes. On November 2nd, for some reason, the owner of the houses Y and Z removed the handles of the pumps, although the water is said to have been excellent in quality to the last. Thenceforward town water was used for all purposes. On the 4th, the pumps were removed, and on examining the well prior to filling it up, traces of soakage were seen just above the water-line, beneath a point at which the house-drain from Y was known to be in close proximity to the well. Shortly before this time attention was directed to the fact that most of the reported attacks of enteric fever had occurred among the households supplied with Z's milk, the only exceptions being those invaded in the area A, where the milk supply was drawn from several dairies, of which Z was one.

Further investigation with regard to Y and Z brought to light the following facts:—On September 24th, Y's son was taken ill, and on the 29th he was found to be suffering from enteric fever. He had returned home on the 16th, after six weeks' absence, the last two days of which had been spent in London and the rest in the country. On October 14th, his father fell ill; on the 17th, the mother; and within a week, two more inmates—making a total of five cases of enteric fever in this house. In Z's house two persons were attacked by enteric fever at the end of October, and a third early in November.

Z's milk came from two farms in the country, M and N. The two supplies were mixed on arrival at Z's house, but 30 houses were supplied direct from M, and 5 from N, and no instance of enteric fever or diarrhœa could be heard of among these 35 households. On the other hand, there were four cases of enteric fever at M, in houses supplied with mixed milk from Z's house, but none at N, although there also Z supplied the same milk to several households in small quantities.

The summer of 1880 was warm and dry. The rainfall in August was 2·2 ins., but nearly 1·5 ins. of this fell in one hour, during a heavy thunderstorm on the 28th. For September, the record was 4·7; for October, 6·6; and for November, 3·6.

Comment upon the several circumstances of this outbreak. Enumerate the principal causes which may give rise to epidemic diffusion of enteric fever, and state clearly the considerations, arising out of the above history, which would lead you to regard one or other cause as having been operative, and to exclude the rest. State also what further evidence you would desire in confirmation of the views (positive and negative) which you adopt. Explain fully what assistance chemistry and bacteriology would be able to render in the investigation of such an outbreak. In the course of your commentary discuss, *firstly*, the probable relation subsisting between the enteric fever epidemic and the prevalence of diarrhœa, and *secondly*, the composition of the population of an average watering-place, as affecting the probable incidence of enteric fever. Assuming the events to have occurred in the present year, what advice would you give to the sanitary authority with regard to the points in which you consider their administration to have been inefficient? Give references in each instance to any Acts of Parliament upon which you would rely in alleging default, or in suggesting action.

Paper in Medicine.

Morning, 10 *to* 1.

1. Describe the symptoms, course and varieties of Angina Pectoris: discuss its pathology and diagnosis, and indicate the principles of treatment.

2. Give a concise description of the chief anatomical changes and clinical signs of Inherited Syphilis.

3. Discuss the therapeutical value of Venæsection, and state what you would regard as sufficient indications for its employment in different diseases.

Afternoon, 2 *to* 5.

1. Give a short account of the effects produced by lesions of different portions of the Cortical Motor Area of the Brain, and discuss their diagnostic value.

2. Describe the symptoms, morbid changes and pathology of Myxœdema, and discuss its treatment.

3. Distinguish the different forms of Hæmaturia due to affections of the Kidneys, pointing out their differential diagnosis. Describe the pathological conditions on which each depends.

Paper in State Medicine.

Morning, 10 *to* 1.

1. Under what conditions, and by what procedure, can a Sanitary Authority deal with (*a*) insanitary dwellings, (*b*) insanitary areas ?

2. How would you obtain the "corrected death-rate" of a given rural district ? In what way does the "corrected death-rate" usually differ from the recorded death-rate, in rural and large urban districts respectively, and to what causes are these differences due ?

3. Enumerate the principal parasites, other than microscopic, which may affect man. Describe, with regard to each, the usual mode of entry, the organs invaded, and the preventive measures which you would recommend.

4. Discuss the relations which have been observed to subsist between the incidence of certain diseases upon man, and conditions of soil as regards (*a*) temperature, and (*b*) water.

5. What considerations, theoretical and practical, have been advanced with regard to the comparative efficiency of the various processes of Disinfection by

Steam? Give your opinion as to the value of each process.

Afternoon, 2 to 5.

1. "There can be no doubt that, ere long, a system of compulsory notification and isolation will replace vaccination. Indeed, I maintain that where isolation and vaccination have been carried out in the face of an epidemic, it is isolation which has been instrumental in staying the outbreak, though vaccination has received the credit."

Comment upon the above quotation in its several bearings, stating, in outline, the arguments which may be adduced on either side.

2. Under what conditions would you regard chemical precipitation, followed by filtration, as a suitable method of purifying the sewage of an inland town? What constituents are found in ordinary sewage? What becomes of each in the course of treatment by an efficient process of the above kind?

3. What is the "expectation of life"? How is it calculated? What effect, if any, would the following conditions produce upon the "expectation of life":—a high birth-rate, a high average mortality from summer diarrhœa? Compare its statistical value with that of the "mean age at death."

4. Describe the mean seasonal curve of mortality for each of the "seven principal zymotic diseases."

Clinical Medicine.

Examination, and Report on Cases, of Patients in a Hospital.

Practical State Medicine.

Sanitary Reporting.

Vivâ-voce Interrogation.

Assuming the present examination-room to be required as a male small-pox ward, state, in detail, what

steps you would take, and what additions and alterations would be necessary, before patients could be admitted.

What other modifications, if any, would you advise if the disease to be isolated were cholera?

Medicine.

Vivâ-voce Interrogation.

Edinburgh B.Sc. (Public Health).

Laboratory Work.

1. Describe a method for the quantitative determination of oxygen dissolved in a sample of potable water.

2. How are micro-organisms classified in relation to their development in oxygen? Describe a method for the cultivation of anærobic organisms.

3. What is a normal solution? How much by weight of—(1) oxalic acid, and (2) butyric acid, are 20 c.c. of a decinormal solution of caustic potash equivalent to?

Practical Work.—1. Quantitative analysis of infants' food. 2. Quantitative analysis of effluent from a sewage farm. 3. Bacteriological examination of samples of potable water.

Physics.

1. How do we measure the momentum and kinetic energy of a moving mass? An engine of 10 tons is moving with a speed of 20 miles per hour, and a cannon ball of 30 lbs. with a speed of 500 feet per second. Compare their momenta and kinetic energies.

2. Distinguish between mass and weight, and describe an experiment which proves that the one is proportional to the other.

3. Assuming that the surface of mercury in a capillary tube is convex, explain, on hydrostatic principles, the depression of the mercury in the tube.

4. Define "viscosity," and explain its nature. Show that it exists in gases, in liquids, and in solids.

5. Contrast the properties of a gas, of a vapour, and of a saturated vapour, and illustrate graphically by means of a Watt's diagram.

6. An object is viewed through a convex lens. Explain when the image is real and when virtual, and sketch in each case the course of the rays from any point of the object to the eye.

7. Describe the spectra of incandescent gases, of liquids, and of solids respectively. Describe the solar spectrum, and explain how it is formed.

8. Define specific heat, and describe accurately any means of determining experimentally the specific heat of a liquid.

9. Explain the terms electromotive force, intensity of current, and resistance, and give the law connecting them. Through what resistance can an electromotive force of 40 volts sustain a current of 8 amperes?

10. An electric current is passed through a dilute solution of sulphuric acid. What are the accompanying phenomena, chemical and thermal?

11. A delicate pocket compass, made in Scotland, is carried to Uganda, and is found to be useless there, because the one pole bears up hard upon the glass cover. Which pole does so? Give also a full explanation of the phenomenon.

12. What is the cause of spring and neap tides?

Geology.

1. Describe the mechanical and chemical action of rain as a geological agent.

2. Distinguish between subsoil and soil, and give an account of their origin.

3. What is a dyke? How may it affect the passage of underground water?

4. Give some account of natural springs. What are the chief kinds of mineral matter found in solution?

5. What kind of geological structure renders a water-supply by Artesian wells possible?

6. Give the mineralogical characters of Augite, Olivine, Calcite, Serpentine, Gypsum, Orthoclase, and Hæmatite.

7. Give the petrographical characters of Basalt, Porphyrite, Gneiss, Chloriteschist, Quartzite, Dolomite, Chalk, Greywacke, and Marble.

8. Draw a section or sections to illustrate the following structures—Anticline, Syncline, Unconformity, Fault, Dyke.

Sanitary Law.

1. Building Bye-Laws.—The Sanitary Authority of a manufacturing town are engaged in the compilation of a code of building bye-laws, and they contemplate adoption of the following clauses as regards filth receptacles:—

(1) The situation, dimensions, materials, and construction of every newly constructed water-closet and privy shall be subject to the approval of the Local Board. (2) Every water-closet or privy shall have an opening, as near to the top as practicable, communicating directly with the external air, or shall be otherwise furnished with sufficient means of ventilation. (3) Every cesspool shall be made water-tight, and shall be arched or covered over, and a pipe or shaft for ventilation shall be carried up from the drain communicating with it from the water-closet or privy into the open air, above the roof of the building for which it is used. (4) The situation, dimensions, materials, and construction of every newly constructed ashpit shall be subject to the approval of the Local Board, and shall be of sufficient size to contain the ashes and dry refuse likely to accumulate between the prescribed visits of the scavenger.

You are required to comment on these proposed clauses, and to point out the defects (if any) from the legal

and the sanitary standpoints respectively. You are at liberty to recast these bye-laws in a sense better calculated to give effect to the principles that you consider should be held in view.

2. Vaccination Acts.—Give a short summary of the leading provisions of the Vaccination Acts now in force.

3. Nuisance from Pig-keeping.—In order to reduce the nuisance from pig-keeping to a minimum, the Sanitary Authorities of two districts—one "urban," the other "rural,"—propose to make bye-laws, to the effect that the occupier of any premises shall not keep swine, or deposit any swine's dung, within the distance of 100 feet from any dwelling-house. State whether such a proposal would be legally justified in each of the cases referred to above, and quote any leading cases of which you have knowledge, in support of your contentions.

Preventive Medicine.

1. State your opinion as to the nature and mode of propagation of Influenza.

2. Describe the precautions which should be taken when an outbreak of Small-pox threatens.

3. Explain the morbid anatomy and pathology of Diphtheria.

Vital Statistics.

1. Density of Population.—Describe the general relation between density of population and the incidence of disease and death. In considering this question, what other factors besides aggregation of population upon area have to be taken into account?

2. Seasonal Prevalence of Disease.—Describe the mean seasonal curve of mortality in each of the so-called "seven principal zymotic diseases."

3. Describe the method by which you would obtain the "corrected death-rate" of a large town. In what respects does the "corrected death-rate" usually differ

from the recorded death-rate in large towns and in country districts respectively? and to what causes are these differences due?

Practical Sanitation.

1. Small-pox Hospital.—The Sanitary Authority of a large town propose to erect an isolation hospital for small-pox, and it is suggested that, with a view to minimise the danger of spreading the disease from such hospital, it should be built in accordance with the accompanying plans and specifications. You are asked to comment on each of such particulars as in your view are likely to favour, as well as those which appear likely to fail, in fulfilling the objects in view.

2. Inspection of Ships.—State concisely the steps you would take to ascertain the sanitary condition of a vessel of, say 2000 tons. To what special points would you direct your attention in the case of a wooden and of an iron vessel respectively?

3. Examination of Water.—You are required to advise a Sanitary Authority as to (1) the wholesomeness of a proposed supply of water, and (2) as to whether or not a certain water supply has been the means of disseminating enteric fever. What value would you attach to chemical and to bacteriological examination respectively of the water, as furnishing data for your guidance in determining these questions?

[*N.B.—All answers to be illustrated as far as possible by sketches.*]

Durham B.Hy.

Sanitary Chemistry and Physics.

1. Describe exactly how you would make a standard solution of silver nitrate, and use the same to estimate the chlorine in a sample of water.

$Ag = 108$. $N = 14$. $O = 16$. $Cl = 35 \cdot 5$. $Na = 23$.

2. How are the "free ammonia" and "albuminoid ammonia" determined in a sample of water?

3. Write an account of Pettenkofer's method for estimating the carbon dioxide in the air.

4. Explain the construction and method of graduation of an aneroid barometer. Describe the attachment and arrangement for making the instrument continuously record its reading. Of what use are continuous records of atmospheric pressure?

5. What do you understand by "radiation of heat"? Illustrate your answer, by reference to (1) the heating of a room; (2) glass fire screens; (3) deposition of dew.

6. Describe the water-gauge and its method of use for measuring the small differences of pressure in experiments on a ventilation system. Mention any recent improvements for obtaining exact readings.

Comparative Pathology.

1. How would you examine a sample of milk for tubercle bacilli? Mention any other pathogenic bacteria which may be conveyed by milk.

2. Describe the life-history of the malarial parasite, showing how man becomes infected by it. What steps can be taken to prevent this?

3. Give a full account of how you would isolate and identify the spirillum of Asiatic cholera from the stool of a patient suffering from this disease.

4. Mention the pathogenic organisms which may be disseminated by milk. Suspicion is attached to the milk supply of a farm as the cause of an outbreak of throat illness in a school. What steps would you take as a bacteriologist to determine the relationship between the outbreak and the milk supply?

5. Describe the Bilharzia hæmatobia, and mention the morbid conditions which may result when man becomes infested with it. How are its ova to be distinguished from those of other human parasites?

6. Describe how you would proceed to make a bacteriological examination of a water-supply used for drinking purposes. What deductions as to the purity of the water would you draw from the number and character of the organisms present?

Sanitary Legislation, Nosology, and Sanitary Medicine.

1. Give some account of the information which is available as to the relation of micro-organisms to the diseases of man.

2. What are the conditions of soil which tend to the production of infantile summer diarrhœa? Give your views as to the methods by which these conditions severally act.

3. Give a summary of the provisions of the Public Health Act, 1875, with respect to the powers of a Local Authority in relation to (*a*) Water Supply, and (*b*) Hospitals.

4. Describe the more common causes of the pollution of the air of towns, and show their effect on human health.

5. Discuss the question of the aërial transmission of the infection of small-pox.

6. Describe the trades specified as "offensive" in the Public Health Act, 1875, and show the chief sources of nuisance in each.

Practical Hygiene, Climatology, etc., and Vital Statistics.

1. Mention the regions of the globe in which bubonic plague is met with, and state what is known respecting the etiology of the disease, and the prophylactic measures necessary to prevent its spread.

2. How do atmospheric conditions affect the spread

of measles, scarlet fever, whooping cough, enteric fever, and small-pox?

3. Describe the methods and appliances in public and domestic use for the purification of water.

4. Show the conditions affecting the increase or decrease of urban populations, collectively and at different age periods, and specify the diseases principally affected thereby.

5. Show briefly the relations of geography, geology, and meteorology, respectively, to health and disease in the British Isles.

6. Describe and criticise the mechanical appliances employed in England for the disinfection of (*a*) excreta; (*b*) rooms, and (*c*) bedding and clothing.

D.P.H. (Scottish Conjoint).

Meteorology.

1. Explain the mercurial barometer, and show the use of the Vernier in reading the height of the column.

2. What thermometric observations should be made in the study of the climate of a locality for medical purposes? and how should the thermometer be placed?

3. In Great Britain what diseases become specially fatal in winter and summer?

Chemistry.

1. State step by step the process for determining the amount of water in milk. How many grammes of water should be contained in 100 c.c. of average milk?

2. What is meant by the cold aqueous extract of flour? How may its amount be determined? What is its normal percentage?

3. What chemical substances render water hard? How may this hardness be measured? How may hardness of water be removed? State the chemical changes which take place in such cases.

Physics.

1. Describe a force pump and a suction pump.
2. What is meant by the critical temperature of a gas, and wherein does a vapour differ from a gas?
3. What is meant by latent heat? How is it determined for water?

Epidemiology and Endemiology.

1. Describe the endemic conditions which favour the development of malarial fever, and the morbific elements upon which it is supposed to depend.
2. Describe the diagnosis of relapsing fever, and its etiology in relation to preventive measures.
3. State the breed of cattle most liable to tuberculosis, the conditions which favour its development in the animal, and those which conduce to its transmission to man; also the measures you would take to prevent danger to mankind from (1) the milk, and (2) the beef.

Practical Sanitation.

1. Small-pox is threatening a community, having broken out in a neighbouring township. State in detail the precautions you should advise the Local Authority to take in order to prevent the appearance of the disease, and, should cases occur, to moderate the extent of the outbreak.
2. What trade is specially placed under the supervision of the Medical Officer of Health? What are the chief provisions of the Act of Parliament regulating it? and how should these be enforced by the Health Officer?
3. Mention the chief points in connection with a self-contained house in a water-carriage town that would justify you granting a certificate that the house in question was uninhabitable. What is the procedure that follows the granting of such a document?

Sanitary Law and Vital Statistics.

1. What is the general influence of (1) age, and (2) sex distribution, on the death-rate of a community? What is meant by a "corrected" death-rate? and what factors must be considered in determining the true death-rate of a watering-place or of a health resort?

2. Define the terms "probable error," "mean error," "average," "mean," as applied in statistical practice. Illustrate them from the following figures—viz. 19, 24, 18, 20, 22, 21, 18, 23, 20, 18, which represent the annual death-rates for a decennium in a certain population.

3. What is the law respecting (1) the exposure of a person suffering from an infectious disorder (*a*) in public places, and (*b*) in public conveyances; (2) respecting the disposal of infected clothing; and (3) the letting of an infected house?

4. What are the provisions of "The Infant Life Protection Act, 1872"? Discuss its value, and the necessity for its existence.

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THE END

Henry Kimpton, 13 *Furnival Street, Holborn, London, E.C.*